

SWENSON

Calculations for a
Light & Power Plant

Mech. Engineering
M. E.
1901

UNIVERSITY OF ILLINOIS
LIBRARY

Class

1901

Book

Sw4

Volume

Je 05-10M



UNIVERSITY OF ILLINOIS

May 31, 1901 190

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Bernard Victor Swenson

ENTITLED Calculations for a Light and Power Plant

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Mechanical Engineer.

L. P. Brackenridge

HEAD OF DEPARTMENT OF Mechanical Engineering.



Digitized by the Internet Archive
in 2013

<http://archive.org/details/calculationsforl00swen>

1701
Sw

CALCULATIONS
for a
LIGHT AND POWER PLANT.

(I.)

INTRODUCTION.

The matter here presented consists of the general calculations and design which resulted from an investigation for the purpose of determining the feasibility of a Central Light and Power Plant for supplying the State Buildings located at Madison, Wisconsin.

The buildings to be supplied are the State Capitol, Governor's Residence, Mendota Hospital (State Hospital for the Insane), State Historical Library, and the various buildings of the University of Wisconsin. The large general map attached (Map No. 1.), shows the location of the buildings, distribution of load, transmission lines, etc., and will be referred to later.

Although the major portion of the work here presented was performed by the writer under the general direction of Professor D. C. Jackson, several important features were worked out by others, acknowledgement of which will be made later. It may be well to state here, however, that the general proposition received considerable attention from Dean J. B. Johnson, Professor D. C. Jackson, Professor Storm Bull, Mr. J. T. W. Jennings (all of the University



of Wisconsin) and from Mr. B. J. Arnold of Chicago.

Present Conditions.

At the present time all of the gas used at the Capitol and University, all electricity used at the Governor's residence for lighting, and nearly all electricity used for light and power at the University, are bought of the Madison Gas & Electric Company. Steam power is generated at the Capitol, Mendota Hospital, and University by local steam plants. Gas is generated at Mendota Hospital by a local gas plant. The elevator at the Capitol is operated by hydraulic power furnished from the University plant. It is proposed to furnish electricity for all lighting and power at the various institutions from a plant located on the shores of Lake Mendota in the University grounds, and to also locate therein the steam heating boilers for the University buildings which are now heated by means of steam distributed through pipes in tunnels on the campus. These pipes and tunnels will remain in use but the pipes will be connected to the boilers in the new plant.

Object of a Central Plant.

The advantages to be derived from operating from a central plant would be several, and they will be considered under separate headings.

ECONOMY OF OPERATION:- The central plant could be operated at an annual cost to the State which would be considerably less than the annual expenditure in this direction under present conditions. This would result principally for several reasons:- first, the thor-

oughly modern equipment proposed for the new plant would permit of reducing the cost of electricity per kilowatt hour below the present price; second, a considerable saving would be made by replacing gas lighting by electric lighting at Mendota Hospital, the Capitol, and at the University. This is especially true concerning the gas lighting at Mendota Hospital, which is so far removed from Madison that it is necessary to have a local gas plant. Third, a similar saving would result in driving the machinery at the various buildings by means of electric motors, the power being supplied from the central station. In this way several small engines at the University and Mendota Hospital, two steam pumps at the latter place, and the hydraulic power at the Capitol, could be replaced by more economical apparatus.

IMPROVEMENT OF SERVICE. This is a very important consideration, probably even more important than the question of greater economy. Present conditions are such that the pressure on the incandescent lighting circuits at the State Historical Library and the University varies as much as ten per cent. or more, and that often within intervals of less than a minute. At times the illumination from gas supplied the Capitol and University is not good and the pressure on the gas mains varies considerably. Also, it is universally recognized that electric lighting has many decided advantages over gas lighting. Again, power supplied by means of electric motors may be much more conveniently applied and controlled than is the case under existing conditions.

REDUCTION OF FIRE RISK. A considerable reduction of the danger from fire would result in the substitution of electricity for gas for lighting purposes in the various buildings under considera-

tion. This is especially the case at the State Capitol and at Mendota Hospital, since in these buildings gas is the only illuminant used at present. At the University but a comparatively small amount of gas is used for lighting purposes. This consideration would have added importance should the State decide to assume its own insurance responsibilities.

SPECIAL ADVANTAGES AT MENDOTA. In addition to the general points mentioned above, there are several special advantages to be obtained at the Capitol, University, and Hospital. Those at the latter place are peculiar to an institution for the insane. The principal advantages here would be the substitution of electricity for gas for lighting purposes within the buildings and the lighting of the grounds by arc lamps. At the present time some of the wards are lighted but very little and some of the "strong rooms" not at all, because of the destructive inclinations of the violent patients accommodated in these quarters. With electric lighting these wards and rooms could be illuminated by specially protected lamps which could be controlled by switches entirely out of reach of the patients. Indeed, it is very questionable as to whether gas should be used as an illuminant in any of the wards of the Hospital, since, with so many irresponsible persons about, either through accident or design, serious results may occur at any time. At present the Hospital grounds are not illuminated. This is not a serious inconvenience in the winter, as the majority of the patients are within doors and those few who have occasion to be out can be carefully watched. However, in the summer the patients are permitted to be outside in the evenings, especially when entertainments such as band concerts are in progress. With the grounds not illuminated it becomes a

difficult matter to observe the movements of all the patients.

SPECIAL ADVANTAGES AT THE CAPITOL. In the Capitol two electrically operated elevators would be installed, and the old hydraulic elevator removed. This would be a decided improvement, as not only is the old elevator a source of constant annoyance but also the building is so long that a second elevator is needed in the other wing. Again, the use of gas as the sole source of illumination in such a large public building is far from being in accordance with thoroughly modern ideas of safety and sanitation.

SPECIAL ADVANTAGES AT THE UNIVERSITY. In addition to advantages arising from the substitution of electricity for gas for illuminating those buildings in which gas is now used, there are several other advantages which would result. One would be the greater convenience and flexibility obtained in the use of electric motors for power purposes. This would be especially apparent in the shops and engineering laboratories where considerable line shafting could be advantageously dispensed with. Another advantage would be that the engineering students would have a well equipped central station right at the University. Tests of the boilers, engines, pumps, dynamos, etc., could be made in this central station without interfering with the operating conditions. This would mean the same as a very considerable increase in laboratory equipment in both Electrical and Mechanical Engineering. A third and very important advantage would be the illumination of the University Campus, by means of arc lamps. At present there are a very few gas lamps used for this purpose. The use of arc lamps for a more extensive lighting of the Campus has been considered as most advisable.

Scope of the Investigation.

Although there are many points to be gained by the establishment of a central light and power plant, it was perfectly evident at the time that the project was first broached that the construction of such a plant would be entirely out of the question unless it could be clearly demonstrated that the annual expenditures in this direction would be reduced, or at the most, would not be in excess of the annual expenditures under conditions such as exist at present.

Since it would probably take at least two years from the time the plant construction is begun before all of the changes would be made, it is evident that a comparison of the annual expenditures must be made upon the basis of conditions as they would exist in not less than two years hence. Again, since the load would be a constantly increasing one (a condition more and more favorable to the central plant), and since it would be necessary to consider this increase in the calculation of the central plant, it has seemed but fair to base the estimates of economy of operation upon the relative annual expenditures in the two cases under conditions which would probably exist in five years time.

A general outline which indicates the ground covered, and which shows the general order in which the subject will be considered, may be made as follows:-

(a) Estimate of Present Distribution of Load.

Prospective Increase within Five Years.

1. University of Wisconsin.

2. State Historical Library.
3. State Capitol.
4. Governor's Residence.
5. Mendota Hospital.

(b) Present Annual Cost of Operating.

Estimated Cost within Five Years under Present Conditions

1. University of Wisconsin.
2. State Historical Library.
3. State Capitol.
4. Governor's Residence.
5. Mendota Hospital.

(c) Preliminary Estimate of the Annual Cost of Operating
the Proposed Central Plant within Five Years.

1. University of Wisconsin.
2. State Historical Library.
3. State Capitol.
4. Governor's Residence.
5. Mendota Hospital.

(d) General Calculations and Design.

1. Maximum Loads.
2. Wiring Calculations.
3. Tunnel Construction.
4. Conduit Construction.
5. Pole Line Construction.

(e) Central Station Design.

1. Building.

2. Boiler Room.
3. Engine and Dynamo Room.

(f) Estimates of Costs.

1. Building, Chimney and Foundations.
2. Boilers and Boiler Room Equipment.
3. Engines, Dynamos, Switchboard, Transformers, Transmission Lines, etc.

(g) Final Estimates of Annual Cost of Operation.

1. By Present System.
2. By Proposed Central Plant.

As has been stated above, several of the parts mentioned in this outline, and which are given later, were worked out by other persons. The design of the building, chimney, and foundations, as well as the estimates of the costs of the same, were furnished by J. T. W. Jennings, Superintending Architect of Buildings and Grounds of the University of Wisconsin. The design of the boiler room and estimates of costs of the same are the work of Storm Bull, Professor of Steam Engineering. The final estimates of costs of construction and operation were made by Dean Johnson, Professors Jackson and Bull, Mr. Jennings, and the writer, after general consultation. As has been indicated above, D. C. Jackson, Professor of Electrical Engineering, was frequently consulted during the progress of the work and many very valuable suggestions were received from him. Finally, acknowledgement is due L. S. Smith, Assistant Professor of Civil Engineering, for the construction of the original maps from which the accompanying drawings were prepared.

(II)

ESTIMATE OF PRESENT DISTRIBUTION OF LOAD.

PROSPECTIVE INCREASE WITHIN FIVE YEARS.

The first step toward determining the character and size of the proposed Central Plant was to ascertain just what amount of power would be required at the various buildings, and when the maximum load would occur in each case. To accomplish this it was necessary to obtain the present load and then to estimate the increase in each instance after a careful study of all of the conditions. These data are also used in determining the probable annual cost of operation.

Present Load.

In determining the present load distribution the monthly light and power bills of the State Capitol, Governor's Residence, and the various buildings of the University were consulted, the bills examined extending over several years.

As the State Historical Library had not yet been completed when this investigation was made, it does not appear in the present load consideration. The present load at the Mendota Hospital was estimated after investigation at the Hospital and after consultation with the Director of the Institution.

A number of the buildings are not used after 6:00 P. M., and others only occasionally after that hour. The majority of the University buildings are lighted between 4:00 P. M. and 6:00 P. M. in the winter months. Again, the shops and many of the laboratories, which take considerable power, are in full operation up to 6:00 P. M. A careful study of the general conditions shows very clearly that the maximum station load will occur between the hours of 5:00 P. M. and 6:00 P. M. The power supplied each building between these hours has, therefore, been estimated. In instances where monthly bills were available the load has been based upon the bill showing the maximum load for the month, since the capacity of the central station would have to be based upon maximum and not average demand. In the majority of cases these maximum loads came in the winter months.

Plates I, II, III, IV, and V show in tabular form the results of the investigation of present load conditions.

Prospective Increase in Load.

Having ascertained the present conditions of load, an estimate was next made of the increase in electric lighting and power which would probably be made in the next five years, due partly to replacing the present steam and hydraulic power by electric power, and partly to the increase in the light and power load due to the increasing requirements of growing institutions. Plates V and VI show in tabular form the estimates which resulted from a consideration of this question.

PRESENT ELECTRIC LIGHTING.											
BUILDING	ROOM	No. OF OUTLETS.	LARGEST BILL.	MONTH OF LARGEST BILL.	TOTAL WATT HOURS.	ESTIMATED AVERAGE LIGHTING HOURS.	AVERAGE No. OF LAMP LAMPS.	TIME OF MAX. LOAD.	No. OF LAMP LAMPS AT TIME OF MAX. LOAD.	No. OF LAMP LAMPS ON FROM 5-6 P.M.	REMARKS.
MAIN BOILER HOUSE		30	9.68	FEB.	121000		25	5-6 P.M.	25	25	1400 26 DAYS - 2 HOURS PER DAY. 8 HRS. PER MONTH ALLOWED AFTER 6 P.M.
GYMNASIUM			20.24	Nov.	253000	4-6 P.M.	75	"	75	75	4200
"			21.12	Dec.	264000	"	80	"	80	80	4400 "
"	RUNNING TRACK	14	1.76	"	22000	5-6 P.M.	14	"	14	14	800 ALL LAMPS BURNING.
"	ARC LIGHTS	18	17.98	"	224700	4-6 P.M.	18 ARCS.	"	18 ARCS	18 ARCS	6000 330 WATT OPEN ARCS, RUN FROM CITY CIRCUIT.
LAW BLDG.		177	25.52	Nov.	319000	"	95	"	95	95	5300 26 DAYS - 2 HRS. PER DAY. 8 HRS. PER MONTH ALLOWED AFTER 6 P.M.
LADIES HALL		495 340 - 16 C.P. 155 - 10 C.P.	195.52	"	2444000	5-10 P.M.	300	"	300	300	16500 30 DAYS, 5 HRS. PER DAY.
SCIENCE HALL	DRAFTING ROOM STEAM LAB. DENT'S OFFICE		3.84	JAN.	48000	5-6 P.M.	36	"	36	36	2000 25 " , 2 " " "
"	PHYSICS DEPT.		25.52	Dec.	319000	4-6 P.M.	110	"	110	110	6400 "
UNIVERSITY HALL			21.12	"	26400	5-6 P.M.	20	"	20	20	1000 25 DAYS, 1 HOUR PER DAY.
MACHINE SHOP.			HUN FROM 'WOOD' ARC MACHINE IN SHOP.			4-6 P.M.	22 ARCS	"	22 ARCS	22 ARCS	10000 2000 C.P. DIRECT CURRENT ARCS.
ELECTRICAL LAB.	ON METER CALLED	22 ARCS	8.80	JAN.	110000	"	3 ARCS	"	3 ARCS	3 ARCS	1000 AVERAGE 350 WATTS.
TESTING LAB. CEMENT LAB.	MACHINE SHOP & METER.	3 ARCS				"	15	"	15	15	900 THREE FOURTHS OF ALL LAMPS BURNING.
OBSERVATORY			3.96	Dec.	49500	3 HOURS PER DAY	10	"	10	10	600 3 HRS. PER DAY. 30 DAYS.
HORT. HALL			1.76	"	22000	4-6 P.M.	7	"	7	7	400 27 DAYS - 2 HRS. PER DAY. 8 HRS. PER MONTH ALLOWED AFTER 6 P.M.
DAIRY BARN			15.23	JAN.	190400	4 HOURS PER DAY	16	"	16	16	900 31 DAYS - 4 HRS. PER DAY. MORNING AND EVENING.

PRESENT ELECTRIC LIGHTING.

BUILDING.	ROOM.	No. OF OUTLETS	No. OF LARGEST BILL.	MONTH OF LARGEST BILL.	TOTAL WATT HOURS.	ESTIMATED AVERAGE LIGHTING HOURS.	AVERAGE No. OF 16 C.P. LAMPS.	TIME OF MAX. LOAD.	No. OF 16 C.P. LAMPS AT TIME OF MAX. LOAD.	No. OF 16 C.P. LAMPS FROM 5-6 P.M.	WATTS FROM 5-6 P.M.	REMARKS.
UNIVERSITY BARN			ON SAME METER AS DAIRY BARN.				11	5-6 P.M.	11	11	600	31 DAYS - 4 HRS. PER DAY. MORNING AND EVENING.
CAPITOL GROUNDS		8 ARCS				6-12 P.M.	8 ARCS	"	8 ARCS.	8 ARCS.	2600	330 WATT, 1200 C.P. ARC LAMPS.
LIBRARY HALL			43.12	Nov.	539000		74	"	74	74	3100	5 HRS. PER DAY. 26 DAYS.
					TOTAL ELECTRIC LIGHTING				WATTS	5-6 P.M.	68100	

PRESENT GAS LIGHTING.

BUILDING	ROOM	No. OF OUTLETS	No. OF LARGEST BILL.	MONTH OF LARGEST BILL.	TOTAL CUBIC FEET.	AVERAGE LIGHTING HOURS.	AVERAGE No. OF 5 FOOT BURNERS.	TIME OF MAX. LOAD.	No. OF 16 C.P. LAMPS AT TIME OF MAX. LOAD.	No. OF 16 C.P. LAMPS FROM 5-6 P.M.	WATTS FROM 5-6 P.M.	REMARKS.
NORTH HALL			14.75	MAR.	11800	4-6 P.M.	15	5-6 P.M.	15	15	800	ABOUT ONE FOURTH OF GAS USED FOR LIGHTING.
CHEMICAL LAB	1ST. FLOOR		5.38	JAN.	4300	5-6 P.M.	10	"	10	10	600	MOST OF GAS IS USED FOR FUEL.
"	2ND "		21.75	FEB.	17400	"	20	"	20	20	1200	FIGURES BASED UPON PROF. HILLYER'S ESTIMATE.
"	3RD "		20.50	MAR.	16400	"	10	"	10	10	600	
MACHINE SHOP			16.50	OCT.	13200	"	2	"	2	2	100	MOST OF GAS IS USED FOR FUEL.

PRESENT ELECTRICAL POWER.												
BUILDING.	ROOM.	MOTOR	LARGEST BILL	MONTH OF LARGEST BILL.	TOTAL WATT HOURS.	AVERAGE OPERATING HOURS.	AVERAGE H.P.	TIME OF MAX. LOAD.	H.P. AT TIME OF MAX. LOAD.	H.P. FROM 5-6 P.M.	WATTS FROM 5-6 P.M.	REMARKS.
LAW BLDG.	VENT. FAN	C.W. 10 H.P.				9-12 A.M.		9-12 A.M.				NOT FIGURED FOR TIME OF MAX. LOAD.
LADIES HALL	"	JENNEY 6 H.P.										NOT RUNNING IN WINTER.
"	"	NORTHERN 1 H.P.										"
"	REFRIGERATOR	NORTHERN 3 H.P.				7-12 A.M.						NOT FIGURED FOR TIME OF MAX. LOAD.
"	PASSENGER ELEVATOR	SULEZ VOLT. 15 H.P.				7-12 A.M. 1-7 P.M.	10	5-6 P.M.	15	10	7500	
"	FREIGHT ELEVATOR	"				7-12 A.M. 12-6 P.M.	10	"	15	10	7500	
DAIRY BARN	RUNNING SEPARATOR	NORTHERN 1 H.P.				5:30-6 A.M. 5-6 P.M.		"			1000	
"	PUMPING WATER	NORTHERN 3 H.P.				2 1/2 HOURS PER DAY.		"			2000	
"	GRINDING FEED	NORTHERN 10 H.P.				1 HOUR PER DAY.		"			6500	NOT FIGURED FOR TIME OF MAX. LOAD.
DAIRY BLDG.	MACHINERY	"				7-12 A.M.						
SCIENCE HALL	VENT. FANS	NORTHERN 15 H.P.				2 HOURS PER DAY.	9	12-1 P.M.	9	9	6600	ONE MOTOR IS RUNNING ON AN AVERAGE BETWEEN 5-6 P.M.
"	"	"				"	9	"	9			
"	HYDRAULIC LAB.	"				2-6 P.M.	10	5-6 P.M.	15	10	7500	
MACHINE SHOP	TESTING LAB.	NORTHERN 3 H.P.				"	3	"	3		2500	
"	ELECTRO-LYTIC LAB.	2 MOTORS				"	3	"	3	3	2500	
ELECTRIC LAB.	ALT. CUR. TESTING		48.48	APR.	606000	8-12 A.M. 2-6 P.M.					3000	
TESTING LAB.	METER CALIB. POWER TEST.	NORTHERN 3 H.P.	1.24	MAY.	31000	2-6 P.M.	1 1/2	5-6 P.M.	1 1/2	1 1/2	1250	DOES NOT RUN EVERY DAY.
								TOTAL WATTS 5-6 P.M.			47850	

PRESENT STEAM POWER.

BUILDING	ROOM	ENGINE	PUMP	AVERAGE OPERATING HOURS	AVERAGE H.P.	TIME OF MAX. LOAD.	H.P. AT TIME OF MAX. LOAD.	H.P. FROM 5-6 P.M.	WATTS FROM 5-6 P.M.	REMARKS.
MACHINE SHOP.	MACHINE SHOP	50 H.P. SHOP.		7 A.M. TO 6 P.M.	25	4-6 P.M.	35	35	26300	
"	ELEC. LAB.	50 H.P. ELEC. LAB.		8 A.M.-1 P.M. 2-6 P.M.	20	"	30	30	22500	
PUMP HOUSE			UNIVERSITY PUMP.	10 TO 15 HRS PER DAY.	25			25		WILL PROBABLY NOT BE CHANGED TO ELECTRIC.

PRESENT HYDRAULIC POWER.

BUILDING	ROOM	APPARATUS	LENGTH OF CYLINDER	DIA. OF CYLINDER	TIME OF TRIP.	AVERAGE OPERATING HOURS.	AVERAGE H.P.	TIME OF MAX. LOAD.	H.P. AT TIME OF MAX. LOAD.	WATTS FROM 5-6 P.M.	REMARKS.
CAPITOL		ELEVATOR	22 FT.	18 IN.	13 SEC.		15		25	15	11300

PROSPECTIVE INCREASE IN ELECTRICAL LIGHTING.

BUILDING	ROOM	NO. OF OUTLETS	ESTIMATED AVERAGE LIGHTING HOURS	AVERAGE NO. OF ELECTRICAL LAMPS	TIME OF MAX. LOAD.	NO. OF ELECTRICAL LAMPS AT TIME OF MAX. LOAD.	WATTS FROM 5-6 P.M.	REMARKS.
LIBRARY		3743	7-10 P.M. 5-6 P.M.	1000	5-6 P.M.	1300	72800	OUTLETS INCREASED FROM 5000 TO 2000 LOAD INCREASED FROM 1200 TO 1500 THIS IS BASED ON ESTIMATE OF MR. SCOTT, SUPT. OF
ENGINEERING BLDG.			4-6 P.M.	200	"	200	11000	PUBLIC BLDGS. THIS IS ALSO IN ACCORDANCE WITH PLANS DRAWN SOME YEARS AGO. IT IS PROPOSED TO LIGHT DOME OF CAPITOL IN THIS ESTIMATE.
CAPITOL BLDG.		500	4-10 P.M.	300	"	300	16500	INCREASE IN DEMAND FROM 350 TO 400 LIGHTS.
MENDOTA GROUNDS		10 ARCS	4-12 P.M.	10 ARCS	"	10 ARCS	4500	
MENDOTA BLDGS.			4-10 P.M.	50	"	50	2800	
UNIVERSITY GROUNDS		15 ARCS	4-12 P.M.	15 ARCS	"	15 ARCS	6700	
				TOTAL	WATTS 5-6 P.M.		114300	

Load from 5:00 P. M. to 6:00 P. M.

The load from 5:00 P. M. to 6:00 P. M. will be the maximum load and will, therefore, determine the capacity of the central station. The load for this period of the day may be summarized as follows:-

	Watts.
Present Electric Lighting.....	68,100
Present Gas Lighting.....	96,750
Present Electric Power.....	47,350

Total Present Light and Electric Power.....212,700

Prospective Increase in Electric Lighting.....	114,300
Prospective Increase in Electric Power.....	123,250

Total Increase in Electric Light and Power...237,550

Total Electric Lighting within Five Years...279,150

Total Electric Power within Five Years.....171,100

Total Station Load within Five Years.....450,250

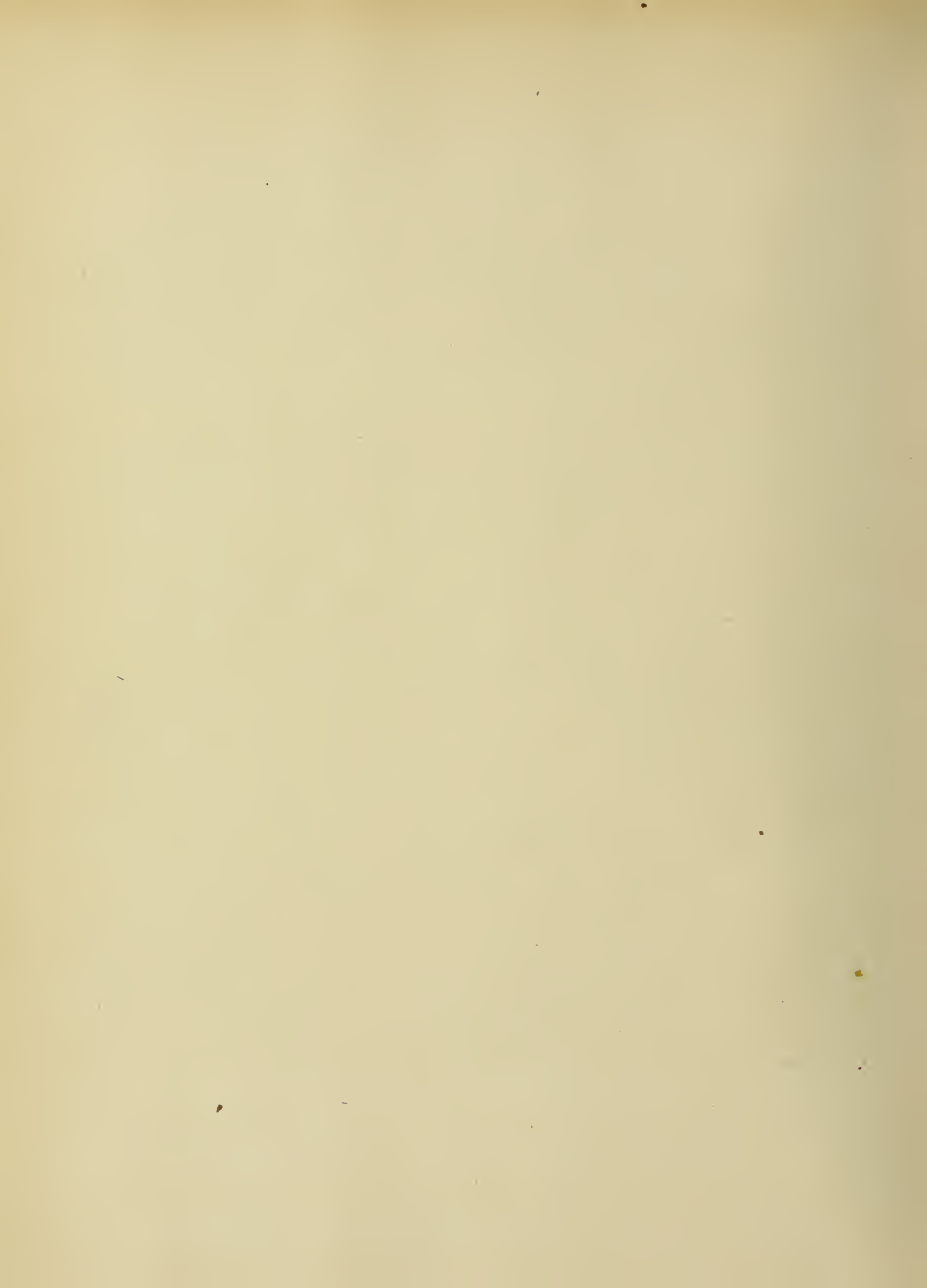
Preliminary Assumptions as to General Design.

Although it has been deemed most advisable to consider the general subject of design later under a separate heading, it is well to have a general idea of the capacity of the station and size of units, before proceeding to the comparison of the annual cost of operating with the annual cost of operating under present conditions. Indeed, it is essential to have these general ideas in mind when estimating some of the items of the annual operating expenses of the proposed plant.

Since half of the maximum load is due to the University buildings and the State Historical Library, and furthermore, since these buildings are to be heated from the central station as well as furnished with light and power, it is evident that the central station should be located upon the University grounds. The maximum load indicates that the central station should have a capacity of about 500 kilowatts, especially if any allowance is to be made for reserve units. This would probably be most advantageously operated if divided into units of about 150 kilowatts capacity each. A very considerable additional boiler capacity is required for heating purposes, the total boiler capacity amounting to about 1900 H. P. This could be advantageously divided into units of about 250 H. P. each.

Such a plant as is outlined, if thoroughly modern and operated economically, ought to be capable of an efficiency of 4 pounds of coal per kilowatt hour.

This value has been used in determining the total coal per annum necessary for light and power.



(III)

PRESENT ANNUAL COST OF OPERATING.

ESTIMATED ANNUAL COST WITHIN FIVE YEARS UNDER PRESENT CONDITIONS.

The present annual operating expenses, including those of the present Central Heating Plant of the University, were obtained by direct consultation of the books of the various institutions considered. It will be seen that the University Heating Plant now supplies steam for the various University Buildings connected by the system of tunnels shown on the detail map of the University Buildings (Map No. 2). It also supplies steam for operating a 50 H. P. Cummmer engine which drives the machinery of the University Shops; a 55 H. P. Weston engine in the Dynamo Laboratory; a 25 H. P. Ideal engine direct connected to a 15 K. W. Weston electric generator, used by the Physics Department and for operating projection lanterns; a small vertical engine which drives a 2 K. W. generator used for the boiler-house lighting; and a steam pump which supplies a reservoir in the dome of University Hall with water from Lake Mendota,* the average head being

*

Some of this water is distributed to some of the University buildings and some is used to operate the elevator at the State Capitol.

about one-hundred and ninety (190) feet. Since it is proposed to supply all of this heating, as well as the light and power, from the Central Plant, these expenses have been included.

At the time these computations were made both Library Hall and North Hall were heated by local furnaces, although it was the intention to extend the tunnels to these buildings in the near future. The only item of expense for heating in each of these cases was the cost of fuel, as the janitor attended to the furnace and his services would be required even when relieved of these duties.

The cost of lighting the Governor's residence is included in the items of expenditure at the Capitol. The estimates here given were made before the State Historical Library and the Engineering Building were opened to the public, although the former building had been heated for two seasons previous. The only item for these two buildings considered in present expenses is that of heating the Library, which is included in the cost of operating the present heating plant.

* This building has since been connected with the present heating plant.

PRESENT ANNUAL OPERATING EXPENSES

University Light and Power:-

Electric Lighting Current	\$2,365.26
Electric Power Current	649.56
Illuminating Gas	537.81
Care of Street Lamps.	20.00
Gas Lighting Labor	70.00
Electric Light and Power Labor.	<u>540.00</u>
Total	\$4,182.63

University Central Heating Plant:-

Coal	\$13,626.85
Boiler House Wages () Engineers	1,500.00
() Firemen	894.75
Boiler Inspection, Insurance	85.00
Sundry Disbursements (including freight, oil, waste, belting, supplies, etc.)	413.33
Repairs (including pipe, pipe-covering, etc.)	492.65
Labor	<u>550.34</u>
Total	\$17,562.92

Heating of South Hall:-

69.5 tons hard coal at \$6.67	463.56
---	--------

Heating of Library Hall:-

84.5 tons hard coal at \$6.67	<u>563.62</u>
---	---------------

Total for Light, Heat and Power \$22,772.73

Capitol Light and Power:-

Cost of Gas Lighting (including maintenance:

legislative year.	\$3,219.44
Cost of Arc Lighting	672.00
Governor's Residence, Lighting	138.00
Capitol Elevator, 15 H.P. at \$30	450.00
Ventilating Fan, 10 H.P. at \$30	<u>300.00</u>
Total	\$4,779.44

Mendota Hospital Light and Power:-

Coal for Gas Plant	\$2,250.00
Labor for Gas Plant (wages and board).	500.00
Materials for Repairs.	<u>50.00</u>
Total	\$2,800.00
Coal for operating Laundry, Shops and Pumps	
(600 tons at \$3.85	2,310.00
Labor*	<u>400.00</u>
Total for Power	\$2,710.00
Total for Light and Power	\$5,510.00

* This man will not be necessary if the power used at the hospital is furnished by electric motors.

A very conservative estimate of the prospective increase in operating expenses was made. No buildings were considered other than those actually built or in progress of construction, and no items of light and power were added excepting either such as necessarily result from changes and improvements then under way, or such as were very definitely understood to be necessary within the next five years.

ESTIMATED ANNUAL COST WITHIN FIVE YEARS UNDER PRESENT CONDITIONS

University:-

Heating of Engineering Building	\$1,090.00
Lighting of Engineering Building (200 lights, 1 hour per day, 260 days per year, 2,912 K.W. hours at \$.08	233.00
Science Hall Elevator (15 H.P. or 11,250 watts. Actual time of operation, 2 hrs. per day for 260 days per year. 22.5 K.W. hours per day at \$.04, or \$.90 per day). .	234.00
Campus Arc Lights (15 at \$84.00 per year)	1,260.00
Total	\$2,817.00

State Historical Library:

Lighting* (200 lamps, 3 hrs. per day, 260 days per year, 2,912 K.W. hrs. at \$.08)	3,495.00
Library Elevators (15 H.P. each; 11,250 W. actual time in use, 2 hrs. per day, 300 days per year, 22,500 watts x 2 hrs. = 45 K.W. hrs. per day, at \$.04 = \$1.80 per day).	540.00
Total	\$4,035.00

* See note at end of Part III.

Capitol:-

Capitol Elevator, North Wing (300 days at \$.90) = \$270.00

Ventilating Fans (one in North and one in South wing; 20 H.P., at \$20.00 if run by electric motors) 400.00

Total \$670.00

The total operating expenses within five years were obtained by combining the present expenses with the estimated increase.

Total Annual Operating Expenses within Five Years
under Present Conditions

Present University Expenses \$22,772.73

Present Capitol Expenses 4,779.44

Present Mendota Hospital Expenses 5,510.00

Total of Present Operating Expenses \$33,062.17

Total Prospective Increase 7,522.00

Total Amount of Expenses within Five Years = \$40,584.17

* * *

NOTE:- The lighting bills of the Library are at present lower than estimated. This is due partly to the fact that the local company can not now supply sufficient power, and partly because the demands within five years will be much greater than they are at present.

(IV)

PRELIMINARY ESTIMATE OF THE ANNUAL COST OF OPERATING
THE PROPOSED CENTRAL PLANT WITHIN FIVE YEARS.

This would include the cost of coal for generating electricity for light and power purposes, and that used for heating the buildings now supplied by the University Heating Plant and for heating the Engineering Building, Library Hall and South Hall. It would also include repairs, renewals, supplies, wages, labor, sundry disbursements, office expenditures and superintendence.

Coal Used for Electric Plant.

In obtaining the coal used for generating electricity it was necessary to ascertain the total kilowatt hours per annum used for light and power at each building. The kilowatt hours per annum supplied from the Central Station was then taken as the sum of these items, due allowance being made for transmission losses.

The estimates of the total kilowatt hours per annum supplied to the various buildings are shown on Plates VII and VIII. Whenever possible, these figures have been based directly upon the actual bills rendered. In other cases it has been necessary to investigate the conditions and even to make tests in some instances

KILOWATT HOURS PER ANNUM.												
BUILDING.	SERVICE.	ANNUAL COST.	COST PER 1000 K.W. HOUR.	COST CU. FT.	TOTAL CU. FT.	No. OF LAMPS DYNAMOS OR ENGINES H.P. EACH	No. OF WATTS EACH	No. OF HOURS PER DAY.	No. OF DAYS PER YEAR.	K.W. HOURS PER ANNUM.	REMARKS.	
UNIVERSITY BLDGS.	ELECTRIC LIGHTING	2365.26	8 CTS.							29566	VARIOUS BUILDINGS NOW SUPPLIED FROM CITY PLANT.	
"	ELECTRIC POWER	649.56	4 CTS.							16239	"	
"	GAS LIGHTING	537.81		1.25	430000					4816	" ONE SFT. GAS BURNER = ONE 16 C.P. LAMP.	
ENGINEERING BLDG.	ELECTRIC LIGHTING					200	56	1	260	2912	INCANDESCENT LAMPS 16 C.P.	
UNIVERSITY CAMPUS	"					15	450	5	365	12319	ENCLOSED ARCS.	
UNIVERSITY SHOPS	STEAM POWER					1	26110	8	260	54300	SHOP ENGINE, COLLEGE MONTHS.	
"	"					1	14920	8	52	6200	SHOP ENGINE, SUMMER MONTHS.	
ELECTRICAL LAB.	"					1	22380	5	260	29100	ELECTRICAL LAB. ENGINE.	
UNIVERSITY SHOPS.	ELECTRIC POWER					1	15000	5	260	19500	GENERATOR USED BY PHYSICS DEPT. AND TO OPERATE LANTERNS.	
SCIENCE HALL	"					1	11190	3	260	8700	ELEVATOR MOTOR.	
"	"					2	6600	2	260	6900	VENTILATING FANS.	
HISTORICAL LIBRARY	ELECTRIC LIGHTING					1000	56	4	260	58240	INCANDESCENT LAMPS 16 C.P.	
"	ELECTRIC POWER					2	22380	2	300	13428	ELEVATOR MOTORS.	

KILOWATT HOURS PER ANNUM.

BUILDING	SERVICE	ANNUAL COST.	COST PER K.W. HOUR	COST PER 1000 CU. FT.	TOTAL CU. FT.	No. OF LAMPS DYNAMOS OR ENGINES	No. OF H.P. EACH	No. OF WATTS EACH	No. OF HOURS PER DAY	No. OF DAYS PER YEAR	K.W. HOURS PER ANNUM.	REMARKS.
CAPITOL	GAS LIGHTING				1643/100	WELLSBACH AND BUTTERFLY BURNERS, AVERAGE 4 CU. FT. PER HOUR.					23010	PRESENT GAS LIGHTING.
"	ELECTRIC LIGHTING										9862	INCREASE FROM 1398 GAS OUTLETS TO 2000 ELECTRIC OUTLETS.
"	"					10		450	5	365	8213	ENCLOSED ARCS, CAPITOL GROUNDS.
"	ELECTRIC POWER					2	15	11190	3	300	20142	ELEVATOR MOTORS.
"	"					2	10	7460	9	300	40284	VENTILATING FANS.
"	"					1	10	7460	9	100	6714	" "
Governor's Res.	ELECTRIC LIGHTING	138.00	8 cts.								1725	INCANDESCENT LIGHTING.
Mendota Hospital	"					1200		56	2 $\frac{2}{3}$	365	57288	ESTIMATE AFTER CONSULTATION WITH HOSPITAL DIRECTOR.
"	ELECTRIC POWER					1	12.5	9325			17456	LAUNDRY OPERATES 36 HRS. PER WEEK.
"	"					1	18.75				1007	SHOP OPERATES 6 HRS. PER MONTH.
"	"	4000 BBLs. OF WATER PER DAY, 57 H.R. HOURS PER DAY, EFFICIENCY 50 %								365	27774	PUMPING WATER FOR GENERAL PURPOSES.
"	"						10		1	365	2723	PUMPING WATER FOR DRINKING PURPOSES.
"	"					6	1	TOTAL OF 5 H.P. HRS. PER DAY.			1361	DUMB WAITERS.
"	ELECTRIC LIGHTING					10		450	3	365	4928	ARC LAMPS HOSPITAL GROUNDS.

before making the calculations.

The total kilowatt hours per annum may be summed up as follows:-

University of Wisconsin:- Kilowatt Hours.

Present Electric Lighting.....29,600

Present Gas Lighting.....4,800

Are Lamos on Campus.....12,300

Engineering Building Lighting.....3,900

Total Lighting.....49,600

Present Electric Power.....16,300

University Shops Power.....60,500

Electric Laboratories Power.....29,100

Physics Department Power.....10,500

Science Hall Elevator.....8,700

Science Hall Ventilating Fans.....6,900

Total Power.....140,900

Total Light and Power.....190,500

Assuming an efficiency of 85 %, the total
supplied to the University from the switchboard
of the Central Plant would be.....224,100

State Historical Library:-

Kilowatt Hours.

Electric Lighting.....58,200

Electric Power.....13,400

 Total Light and Power.....71,600

Assuming an efficiency of 85 %, the total
 supplied to the Library from the Central Plant
 switchboard would be.....84,300

State Capitol and Governor's Residence:-

Incandescent Lighting.....32,900

Arc Lighting.....8,200

Governor's Residence, Lighting.....1,700

 Total Lighting.....42,800

Capitol Elevators.....20,100

Ventilating Fans.....47,000

 Total Power.....67,100

Total Light and Power..... 109,900

Assuming an efficiency of 85 %, the total
 supplied the Capitol and Governor's Residence
 from the switchboard of the Central Plant
 would be.....129,300

Mendota Hospital:-

Kilowatt Hours.

Incandescent Lighting.....57,300

Arc Lighting.....4,900

 Total Lighting.....62,200

Power for Laundry.....17,500

Power for Shops.....1,000

Power for Pumping Water for Drinking Purposes.....2,700

Power for Pumping Water for General Purposes.....27,800

Power for Dumb Waiters.....1,400

 Total Power.....50,400

Total for Light and Power.....112,600

Assuming an efficiency of 80 %, the total
 supplied to Mendota Hospital from the switch-
 board of the Central Plant would be.....140,750

The total kilowatt hours per annum at the Central Plant may be briefly summarized as follows:-

	Kilowatt Hours.
Total at Switchboard for University.....	224,100
Total at Switchboard for Library.....	84,300
Total at Switchboard for Capitol.....	129,600
Total at Switchboard for Mendota Hospital.....	140,750
Total at Switchboard.....	578,750

It was estimated that the proposed electric plant could be operated upon 4 pounds of coal per kilowatt hour.

	Tons.
578,750 K. W. hrs. at 4 lbs. coal per K. W. hr.....	1,157

The cost of coal for light and power is based upon the price per ton paid by the University in 1900 - 1901.

1,157 tons of coal at \$3.45 per ton.....	\$3,991.65
---	------------

Coal used for Heating.

In obtaining the coal used for heating buildings now connected with the University Heating Plant it was necessary to deduct from the total coal that which was used for power purposes. The total coal supplied to the University Heating Plant for the year 1899 - 1900 amounted to 4,344 tons and cost \$13,626.85.

The amount of coal used for power purposes for that year was estimated as follows:-

University Shops:-

Tons.

30 H. P., 8 hrs. per day, 260 days per year;

62,400 H. P. hrs., at 5 lbs. coal per H. P. hr.....156

Electrical Laboratory:-

25 H. P., 5 hrs. per day, 260 days per year,

32,500 H. P. hrs., at 5 lbs. coal per H. P. hr.....32

Physics Department (Including Lantern Current).

20 H. P., 5 hrs. per day, 260 days per year;

2,600 H. P. hrs., at 5 lbs. coal per H. P. hr.....65

Capitol Elevator (Hydraulic):-

Tons.

5,000 lbs. water per trip, 225 trips
 per day, 300 days per year; 192 ft. head*,
 64,800,000,000 ft. lbs. of work done by
 pump; at a duty of 50,000,000 ft. lbs. per
 1,000 lbs. of steam this would be 1,296,000
 lbs. of steam. Taking 7 lbs. of steam per
 lb. of coal, this gives.....93

Boiler House Lights:-

15 lamps, 3,000 hrs. per year; 45,000 lamp hrs.,
 2,520,000 watt hrs. per year. At 40 % effi-
 ciency from engine indicated to lamps, this
 amounts to 8,450 H. P. hrs. per year. Tak-
 ing 7 lbs. of coal per indicated H. P. per
 hour, this gives.....30

Total coal used at University Heating Plant for
 Power Purposes.....428

Cost of coal used at University Heating Plant
 for Power Purposes, at \$3.14 per ton..... \$1,337.64

*

The head of 192 feet is from surface of Lake Mendota to the
 level in the reservoir in the University Hall dome.

In estimating the coal used at the Central Plant for heating purposes it was assumed that practically the same amount of coal would be necessary to heat the buildings as is used under the present conditions, since any slight increase in loss due to longer mains would be more than compensated for by the increased efficiency under the new system.

The cost of coal used for heating was estimated as follows:-

Annual Cost of Coal at University

Heating Plant, (year 1899 - 1900)...\$13,626.85

Deduct for Power Purposes.....1,337.64

Total coal used for heating buildings now

connected with University Heating Plant*.... \$12,289.21

Coal for heating Library Hall.....563.62

Coal for heating South Hall.....433.53

Coal for heating Engineering Building.....\$1,090.00

Total Annual Cost of Coal for heating.....\$14,406.39

* This includes coal used for pumping water for University buildings.

Wages of Employees.

It is estimated that during the ten months of the year when the University is in session it will be necessary to employ three engineers and three firemen with shifts of eight hours, one engineer and one fireman being on duty at any one time.

During two summer months the work would become so light that it could be performed by two engineers and two firemen working in twelve hour shifts. A wiper would also be necessary during ten months of the year. In addition to this force there should be one electrician and one steam fitter, each of whom would be employed the year around.

The wages of regular employees may be summed up as follows:-

1 Chief Engineer (12 months).....	\$900.00
1 Assistant Engineer (12 months).....	480.00
2 Firemen (12 months).....	960.00
1 Assistant Engineer (10 months).....	400.00
1 Fireman (10 months).....	400.00
1 Wiper (10 months).....	400.00
1 Electrician (12 months).....	720.00
1 Steam Fitter (12 months).....	730.00

Total.....\$5,040.00

Incandescent Lamp Renewals.

The incandescent lamp renewals per annum were estimated by finding the total kilowatt hours per annum used for lighting and assuming 750 hours as the average life of lamps. The estimate is as follows:-

Kilowatt Hours.

Total Incandescent Lighting at the University.....	37,300
Total Incandescent Lighting at the Library.....	53,200
Total Incandescent Lighting at the Capitol.....	34,600
Total Incandescent Lighting at Mendota Hospital.....	57,300
Total.....	187,400

Assuming 56 watt lamps and 750 hrs. life,
this would mean 4,500 lamps per annum.

Cost of 4,500 incandescent lamps at \$.18.....\$810.00

The number of arc light carbons was estimated by considering the total number of arc lamp hrs. per year and assuming 100 hrs. for 1 1/2 carbons. This amounted to 620 carbons per annum and 1,000 carbons were considered as necessary. Cost of 1,000 carbons at \$25.00.....\$25.00

Summary of Annual Operating Expenses

Several other items, such as extra labor, repairs, supplies, superintendence, etc., have been estimated, the figures being based upon actual expenses whenever possible. A summary of the annual operating expenses of the proposed Central Plant may be made as follows:-

Total Coal for Light and Power	\$3,991.65
Total Coal for Heating	14,406.39
Total Wages	5,040.00
Incandescent Lamp Renewals	810.00
Arc Carbons	25.00
Boiler Inspection, Insurance	150.00
Repairs on Heating Plant [*] (including pipe, pipe-covering, etc.)	600.00
Repairs on Light and Power Plant (including repairs on machinery, transmission lines, etc.)	500.00
Extra Labor	250.00
Sundry Disbursements (including freight, oil, waste, lamp globes, general supplies, etc.)	1,000.00
Superintendence and Office Expenditures	1,500.00
Total Annual Cost of Operation	\$28,273.04

* The repairs on the heating plant are based directly upon the present annual expenditure in this direction.

(v)

GENERAL CALCULATIONS AND DESIGN.

The general conditions of the problem, considered in Parts I and II, may be briefly reviewed as follows:-

The maximum load within five years would amount to about 500 kilowatts and would occur between 5:00 P. M. and 6:00 P. M. Fully one-half of this power is supplied to the various buildings of the University and the Historical Library (located on the University Campus); many of these buildings (including the Historical Library) are to be heated by steam supplied from the proposed central station. These considerations resulted in locating the central station on the University Campus. The site selected, indicated by No. 1 on the maps, is situated on the edge of Lake Mendota and is not far removed from the present Central Heating Plant of the University, which is the unnumbered building directly north of Science Hall (No. 9).

Maximum Loads.

The general method of obtaining the distribution of load was considered in Part II, and the 5:00 P. M. to 6:00 P. M. load was shown in Plates I, II, III, IV, V, and VI.

These loads are shown on Map No. 1 in the table entitled "Distribution of Load." In this table are also given the distances of

the various buildings from the central station and the probable total kilowatt hours per annum for the Capitol and Governor's residence, Mendota Hospital, Historical Library, and the University buildings. It will be remembered that these latter figures were obtained by a consideration of the present yearly consumption and estimates of the additional annual consumption under the new conditions after five years' growth.

The distance from the proposed central station to the Capitol is over one mile, and that to Mendota Hospital is over seven miles. About two-fifths of the ultimate electric generating capacity will be used for power. These considerations led to the choice of the three phase alternating current system for the electric plant.

It is proposed to make use of the steam heating tunnels on the University Campus in running circuits to the various buildings so connected. With unprotected rubber covered wires (proposed for tunnel wiring) the line pressure in the tunnels should not be greater than about 500 volts. This is sufficiently high for the comparatively short distances to the Historical Library and the various University buildings. With this pressure motors may be operated directly and it becomes necessary to use transformers only for the lighting service at the buildings mentioned. A little computation showed that the proper pressure to use in transmitting power to Mendota Hospital would be in the neighborhood of 5,000 volts, and to the Capitol, at least 2,000 volts.

Since more than one-half of the power is used at 500 volts pressure, and since, moreover, it is desirable for many reasons to have comparatively low pressure generators, this has been taken as the gen-

erator pressure. It then becomes necessary to use transformers at the central station only for the transmission lines to the Capitol and Mendota Hospital. Since 5,000 volts is not excessively high, it has been thought advisable to transmit to the Capitol as well as to Mendota Hospital at this pressure, thus avoiding two different line pressures.

The Central Station.

Before entering upon the design of the central station it is desirable to know just what circuits are necessary, where these circuits run, the power supplied to each, etc. The central station will, therefore, be considered later (Part VI), and we will now proceed to a discussion of the transmission lines.

The Transmission Lines.

It has been considered necessary to place all wires underground which are run in the immediate neighborhood of the Capitol and the University. As far as possible this has been done by running the circuits in the tunnels on the Campus. However, it has been found necessary to install four short conduit lines. Three of these are for the 5,000 volt lines, and one leads north from University Hall (No. 13) to a point, L, on the University grounds, from which point a pole line extends to the various University buildings to the north.

The various circuits, so far as practicable, have been represented on Maps Nos. 1 and 2. These maps show, in general, the location of the University buildings, the Capitol, the Governor's resi-

idence, and the Mendota Hospital Grounds.

The wiring in the tunnels to the Historical Library and the various University buildings, consists of rubber covered wire. The tunnel wiring is not represented on the map but is shown on Map No. 1 in the table entitled "Description of Circuits."

The underground construction consists of lead covered cables placed in conduits. It is represented on the maps by blue lines for single phase, and yellow lines for three phase circuits.

When two or more circuits are necessary, each circuit is run in a single lead cable, and the various lead cables placed in separate conduit ducts. A blue line thus indicates one two wire cable, and a yellow line indicates one three wire cable. The conduit should be Camp Duct, MoRoy Conduit, or the equivalent. The pole line construction is represented on the map by red lines for single phase, and green lines for three phase circuits. A red line thus indicates one two wire circuit, and a green line indicates one three wire circuit.

The Mendota Hospital Line is laid down on the proposal that the State shall secure a right of way for the pole line alongside the right of way of the C. & N. W. R'y. for the distance between the points E. and F. (Map No. 1).

The various lettered points on the maps are in general places at which taps are made or where the character of the circuit changes. They may be briefly explained as follows:-

- A.- Beginning of pole line between the University and the Capitol.
End of conduit from the central station.
- B.- End of the pole line between the University and the Capitol.
Beginning of conduit to Capitol.

- C.- Beginning of the Mendota Hospital pole line, after leaving the Capitol.
End of conduit from Capitol.
- D.- Branch from the Mendota Hospital pole line, leading to the Governor's residence.
- E.- Intersection of Washington Ave. with the C. & N. W. R'y.
End of the 50 ft. pole line to Mendota Hospital and beginning of the 35 ft. pole line.
- F.- Intersection of C. & N. W. R'y with the highway leading to Mendota Hospital.
- G.- Tap from Science Hall line leading to Engineering Building.
- H.- Tap from Ladies' Hall line leading to Law Building.
- I.- Tap from State Historical Library circuit to Gymnasium.
- J.- Tap from Ladies' Hall line leading to Library Hall.
- K.- Tap from University Hall line to North and South Halls.
- L.- Beginning of pole line to Dairy Building, and end of conduit line from University Hall. The dairy Building circuit, which supplies all the farm buildings and the Observatory, is run through the tunnels as far as University Hall, since the pressure is but 500 volts. This saves about 1,000 feet of conduit construction.
- N.- Tap from Dairy Building line to Observatory.
- P.- Tap from Dairy Building line leading to Dairy Barn.
- Q.- Tap from Dairy Building line to Horticultural Hall and proposed Agricultural Hall.
- R.- Tap from Dairy Barn line leading to University Barn.

In calculating the sizes and lengths of wires it has been necessary to know the distances between various points. Those which have been used in the calculations are given below.

<u>From</u>	<u>To.</u>	<u>Distance in Feet.</u>
Central Station	Gymnasium.	1550
Central Station	Historical Library.	1250

<u>From</u>	<u>To</u>	<u>Distance in Feet.</u>
Central Station	Science Hall.	700
Central Station	Chemical Laboratory	400
Central Station	Machine Shops & Elec. Lab.	350
Central Station	Engineering Building	1000
Central Station	Law Building	1150
Central Station	Library Hall	1250
Central Station	Ladies' Hall	1400
Central Station	North Hall	1300
Central Station	South Hall	1450
Central Station	University Hall	1600
Central Station	Observatory	3300
Central Station	Horticultural Hall	4000
Central Station	Dairy Building	3950
Central Station	University Barn	5000
Central Station	Dairy Barn	5750
Central Station	State Capitol	7700
Central Station	Mendota Hospital	38600
D	Governor's Residence	2600
University Hall	L	600
L	Dairy Building	1650
N	Observatory	400
Q	Horticultural Building	150
P	Dairy Barn	2200
R	University Barn	100
Central Station	A	2200
A	B	4400

<u>From</u>	<u>To</u>	<u>Distance in Feet.</u>
A	Capitol	1100
Capitol	C	800
C	E	6600
E	Mendota Hospital	22500
Capitol	Governor's Residence	4400

WIRING CALCULATIONS. All wiring (except the Mendota Hospital line) has been calculated upon the assumption of a five per cent. line loss. The Mendota Hospital line loss has been taken at ten per cent. Separate circuits for light and power are proposed, except for the Mendota Hospital. In calculating the three phase lines the calculation has been made the same as for single phase and wire of half the calculated cross section has been taken. This is the general method of calculating three phase lines and gives the size of wire for the same per cent. loss as in the single phase, the weight of copper being seventy-five per cent. of that of the single phase line.

In all cases the wiring has been figured by considering the maximum load which might be supplied to the building which in several instances exceeds the 5:00 P. M. to 6:00 P. M. load. The wiring calculations have been condensed and placed on Plates IX and X. The size of wire has been calculated in each case upon the assumption that independent lines would be run to the various buildings. The were afterwards combined to some extent, certain buildings being grouped and supplied from the same circuit. This grouping is shown on Plate XI.

WIRING CALCULATIONS.

BUILDING.	CIRCUIT.	MAX. LOAD (WATTS)	POWER FACTOR (PERCENT)	MAX. APPARENT WATTS	LINE PRESSURE (VOLTS)	MAX. CURRENT / PHASE (AMPERES)	LINE LOSS (PERCENT)	LINE DROP (PERCENT)	PRESSURE DROP (VOLTS)	TOTAL LENGTH OF PHASE CIRCUIT (FEET)	SIZE OF WIRE.	No. OF PHASES	REMARKS.
GYMNASIUM	LIGHT	17400	90	19300	500	38.6	5	4.5	22.5	3100	2	1	RUN NO. 2 WIRE BEYOND LIBRARY. TAP ON LIBRARY CIRCUIT.
STATE HIST. LIBRARY.	"	72500	90	80550	500	161.1	5	4.5	22.5	2500	0	1	TWO PAIRS OF FEEDERS.
"	POWER	22600	80	28250	500	56.5	5	4.0	20.0	2500	4	3	2 ELEVATORS. ONLY ONE CONSIDERED IN THE 5-6 P.M. LOAD.
SCIENCE HALL	LIGHT	10100	90	11200	500	22.4	5	4.5	22.5	1400	7	1	USE NO. 6 WIRE.
"	POWER	39500	80	49400	500	94.8	5	4.0	20.0	1400	4	3	THIS INCLUDES ONE VENT FAN NOT INCLUDED IN 5-6 P.M. LOAD.
CHEMICAL LAB.	LIGHT	2400	90	2670	500	5.3	5	4.5	22.5	800	17	1	RUN FROM SHOP LIGHT MAINS USING NO. 10 WIRE.
MACHINE SHOP.	"	12250	90	13600	500	27.2	5	4.5	22.5	700	10	1	USE NO. 8 WIRE ON ACCOUNT OF CHEMICAL LAB. BRANCH.
"	POWER	66550	80	83200	500	166.4	5	4.0	20.0	700	5	3	USE NO. 3 WIRE ON ACCOUNT OF LARGE CURRENT.
ENGINEERING BLDG.	LIGHT	11000	90	12200	500	24.4	5	4.5	22.5	2000	6	1	
"	POWER	21000	80	26250	500	64.6	5	4.0	20.0	1950	4	3	
UNIVERSITY HALL	LIGHT	5600	90	6200	500	12.4	5	4.5	22.5	3250	7	1	USE NO. 6 WIRE. WIRING FIGURED ON BASIS OF 100 LAMPS MAX. 1/5 TWICE 5-6 P.M. LOAD.
NORTH HALL.	"	800	90	900	500	1.8	5	4.5	22.5	2550	16	1	TRANSFORMER PLACED IN TUNNEL NEAR NORTH HALL WITH PRIMARY CONNECTED TO UNIVERSITY HALL 500VOLT MAINS
SOUTH HALL	"	1100	90	1200	500	2.4	5	4.5	22.5	2850	15	1	SECONDARY LEADS NO. 10 RUN TO N. & S. HALLS
LADIES HALL	"	16500	90	18300	500	36.6	5	4.5	22.5	2800	3	1	
"	POWER	22500	80	28100	500	56.2	5	4.0	20.0	2800	3	3	RUN NO. 2 TO LAW BLDG. & NO. 3 BEYOND. CONNECT LAW POWER CIRCUIT TO THIS MAIN.
LAW BLDG.	"	7500	80	9400	500	18.8	5	4.0	20.0	2300	9	3	TAP OF LADIES HALL CIRCUIT (POWER) USE NO. 10 WIRE.

WIRING CALCULATIONS.

BUILDING.	CIRCUIT	MAX. LOAD (WATTS)	POWER FACTOR (PERCENT)	MAX. APPARENT (WATTS)	LINE PRESSURE (VOLTS)	MAX. CURRENT (AMPERES)	LINE LOSS (PERCENT)	LINE "DROP" (PERCENT)	PRESSURE "DROP" (VOLTS)	TOTAL LENGTH OF 1 PHASE CIRCUIT (FEET)	SIZE OF WIRE.	No. OF PHASES	REMARKS.
LAW BLDG.	LIGHT	5300	90	6000	500	12.0	5	4.5	22.5	2300	9	1	COMBINE WITH LIBRARY HALL USING No. 5
LIBRARY HALL	"	5600	90	6200	500	12.4	5	4.5	22.5	2500	8	1	COMBINE WITH LAW BLDG. USING No. 5 USE No. 10 BEYOND JUNCTION.
OBSERVATORY	"	650	90	700	500	1.4	5	4.5	22.5	6600	13	1	RUN ONE SET OF LIGHTING MAINS
HORT. BLDG.	"	710	90	750	500	1.5	5	4.5	22.5	8000	13	1	(SINGLE PHASE FEEDERS) FROM CENTRAL STATION TO DAIRY BLDG., HORT. HALL AND AGRICULTURAL HALL, USING No. 2 WIRE. CONTINUE TO DAIRY BARN USING No. 8 WIRE.
DAIRY BLDG.	"	800	90	900	500	1.8	5	4.5	22.5	7900	12	1	RUN ONE SET OF POWER FEEDERS (3 PHASE) USING No. 0 WIRE. FROM CENTRAL STATION TO DAIRY BUILDING.
"	POWER	7500	80	9400	500	18.8	5	4.0	20.0	7900	5	3	CONTINUE TO DAIRY BARN, USING No. 2 WIRE.
UNIVERSITY BARN	LIGHT	600	90	650	500	1.3	5	4.5	22.5	10000	12	1	
DAIRY BARN	"	900	90	1000	500	2.0	5	4.5	22.5	11500	10	1	
"	POWER	9500	80	11900	500	24.0	5	4.0	20.0	11500	2	3	
MENDOTA	LIGHT & POWER	76450	80	95500	5000	19.1	10	8.0	400.0	76000	7	3	USE No. 6 WIRE, ONE 25 H.P. WATER PUMPING MOTOR, NOT IN 5-6 P.M. LOAD.
GOVERNOR'S RES.	LIGHT	3800	90	4200	1000	4.2	5	4.5	45.0	8800	12	1	RUN FROM CAPITOL LIGHT MAINS. USE No. 10 WIRE.
CAPITOL	"	88500	90	98300	5000	20.0	5	4.5	22.5	15400	8	1	
"	POWER	44800	80	56000	5000	11.2	5	4.0	20.0	15400	14	3	THIS INCLUDES ONE ELEVATOR AND TWO VENT. FANS (10 EACH) NOT IN 5-6 P.M. LOAD.
AGRIC. HALL	LIGHT	5500	90	6100	500	12.2	5	4.5	22.5	7900	4	1	SEE NOTE ABOVE
"	POWER	7500	80	9400	500	18.8	5	4.0	20.0	7900	5	3	"

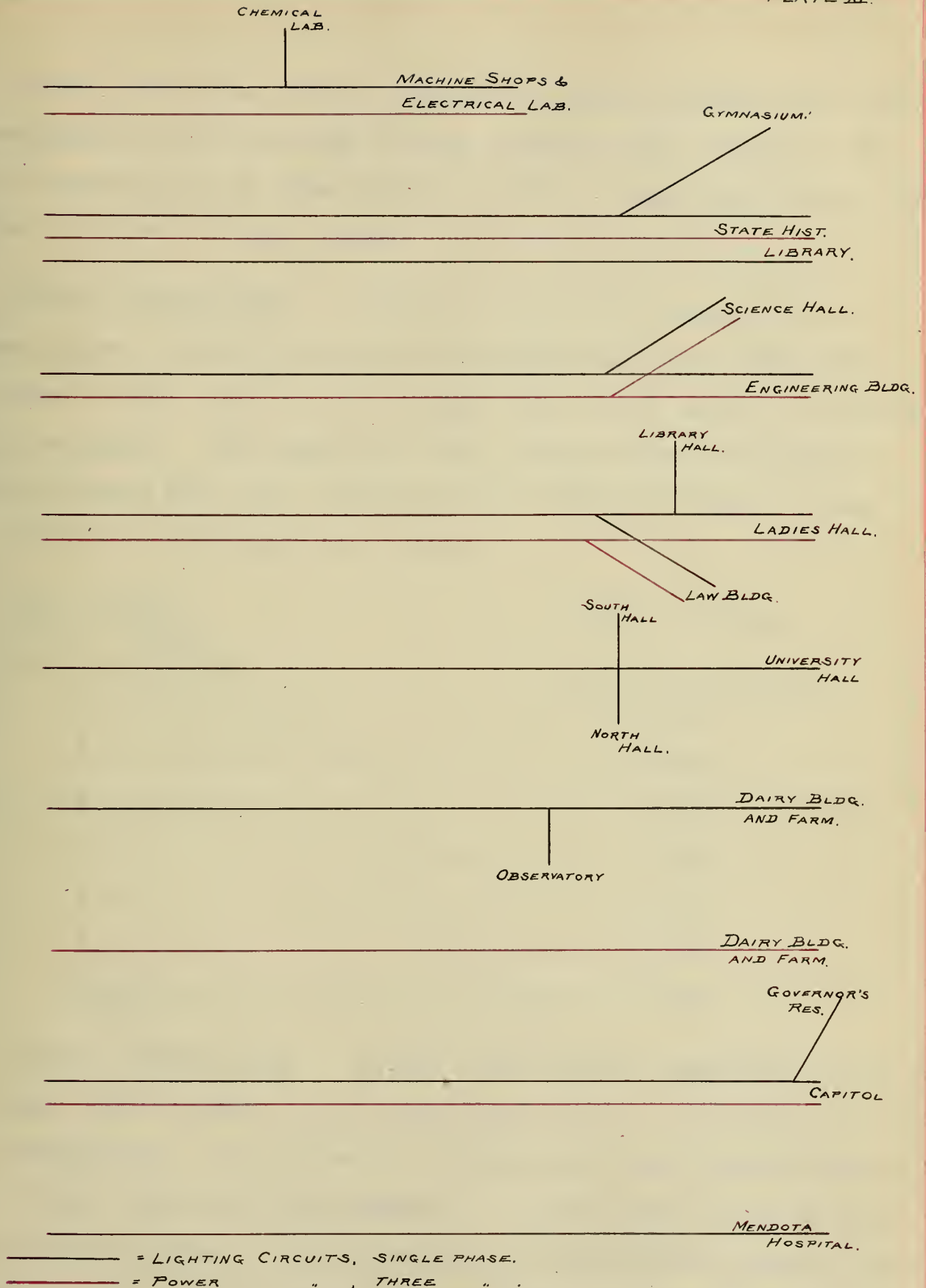


DIAGRAM OF FEEDER CIRCUITS.

Since some of the circuits consist of rubber covered wire, some of weatherproof wire and some of lead covered cable, and still others of combinations of these three, the size, length, and kind of conductor are shown for each circuit on Plates XII and XIII.

TUNNEL CONSTRUCTION. The wire used in the tunnels will be rubber covered and will be put up with porcelain cleats which will be spaced 10 feet apart on the straight runs and at shorter intervals where required. The amount of rubber covered wire to be used in connection with the tunnel construction is shown on Plates XII and XIII and may be summarized as follows:-

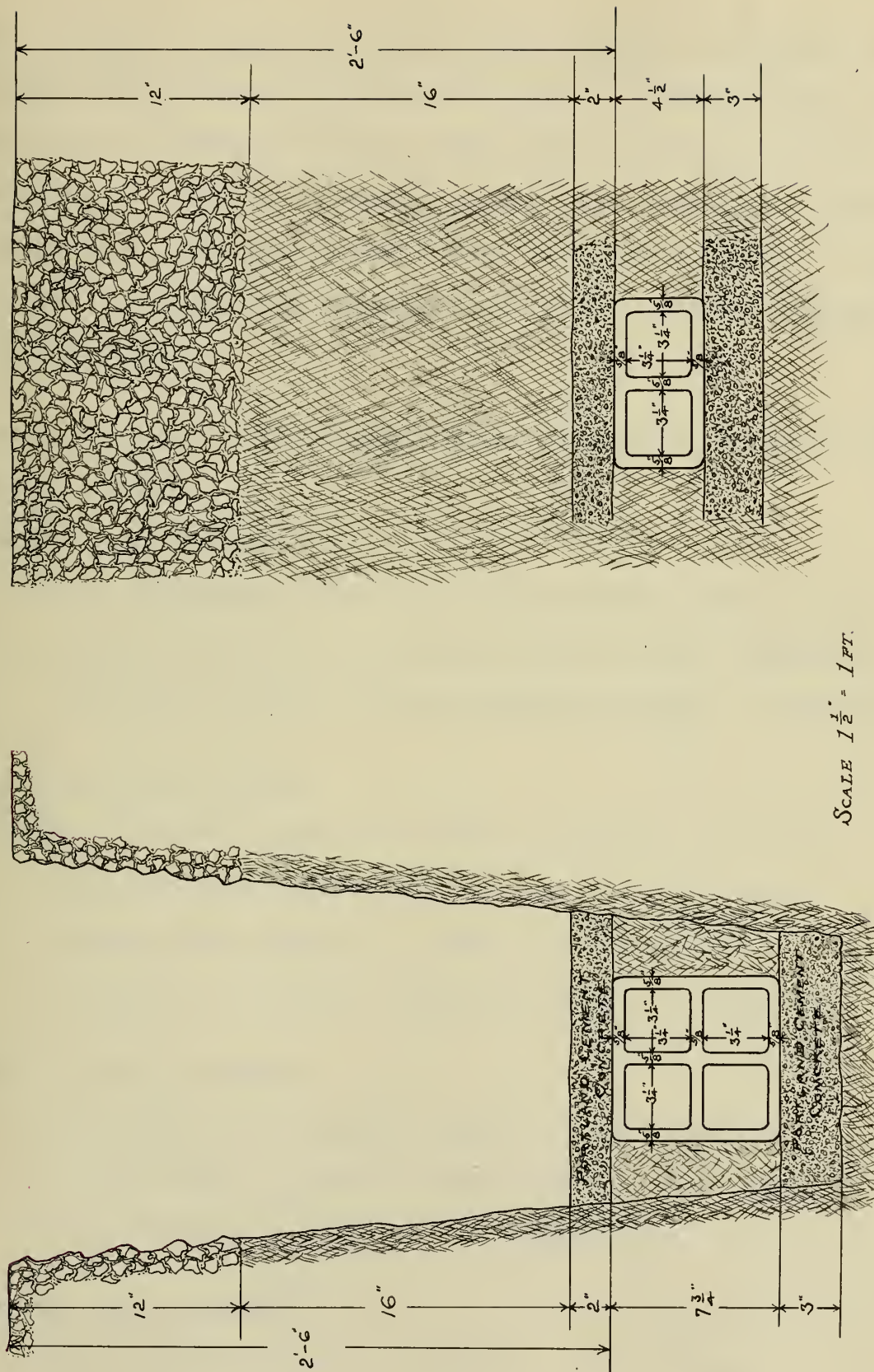
Size of Wire (B. & S. Gauge).	Number of Feet.
0.....	9,800
2.....	11,000
3.....	3,000
4.....	6,500
6.....	4,200
8.....	1,000
10.....	1,700

CONDUIT CONSTRUCTION. As was stated at the beginning of Part V, Camp Duot, McRoy conduit, or the equivalent is to be used for the conduit construction. In the general design and in the calculations of costs McRoy conduit has been assumed. A two duct conduit is necessary between points 16 and L (Map No. 2), and between points 2 and C (Map No. 1). Between points 1 and A (Map No. 2) and points B and

2 (Map No. 1) a three duct conduit would be necessary. However, since at some future time it might be necessary to run the lighting circuit to Mendota Hospital independent of the power circuit, it was thought desirable to install a four duct circuit in these cases, particularly since the cost of laying a four duct conduit is less than that of laying a three duct conduit, because of the reduced width in the four duct conduit.

LAYING THE CONDUIT. The trench is to be dug to such a depth that the top of the conduit when in place shall not be less than thirty inches from the surface of the street or ground in which the conduit is laid. The bottom of the trench is to be carefully graded so that water will be drained into manholes. In case of level sections the grading is to be so performed that the conduit is slightly higher in the middle of such sections in order to insure proper drainage to the manholes. The bottom of the trench is to have a uniform layer of Portland cement concrete three inches thick. The ducts are to be placed on this concrete, carefully aligned, and the joints cemented. The ducts are to be kept perfectly smooth inside and present no obstructions, particularly at joints. A straight line is to be preserved between manholes, as far as possible. A wire is to be placed in each duct, to be used afterwards in drawing in the lead covered cables. After the conduit has been placed in position, a uniform layer of Portland cement concrete two inches thick is to be placed on top of the conduit to serve as a protection for the same. Plate XIV shows sections of construction for both the two and the four duct conduits.

MANHOLES. The manholes are placed about 350 feet apart on the



TWO DUCT CONDUIT
TRENCH CLOSED.

FOUR DUCT CONDUIT
TRENCH OPEN.

average. They are placed at all bends and also at the ends of sections when these ends are not at buildings. Plate XV shows the four sections of conduit and the number and location of manholes for each section. The total number of manholes required is thirteen. They should be 4 feet square and 8 feet deep, with covers 30 inches in diameter. The general construction of the proposed manhole is shown on Plate XVI.

CONDUIT LINES. The conduit lines necessary, shown on Plate XV, are the following:-

One Two Duct Conduit,

From University Hall (No. 18) to point L (Map No. 2).

Length of 800 feet, contains one No. 2 two conductor cable and one No. 0 three conductor cable. 2 manholes.

One Four Duct Conduit,

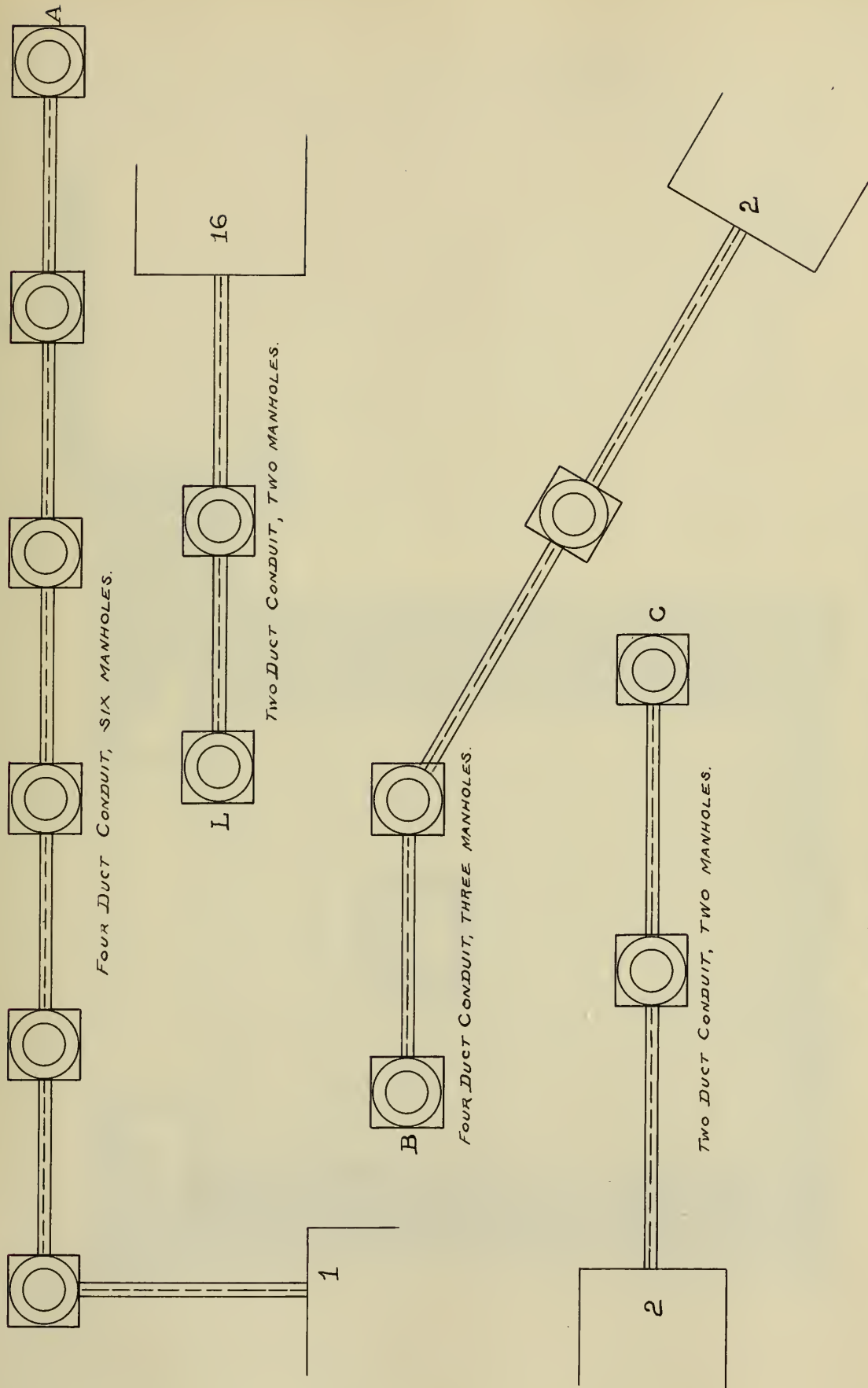
From Central Station to point A (Map No. 2). Distance of 2,200 feet, contains one No. 8 two conductor cable, one No. 6 three conductor cable, and one No. 10 three conductor cable. 3 manholes.

One Four Duct Conduit,

From point B to Capitol (Map No. 1). Distance of 1,100 feet, contains same cables as from central station to point A. 3 manholes.

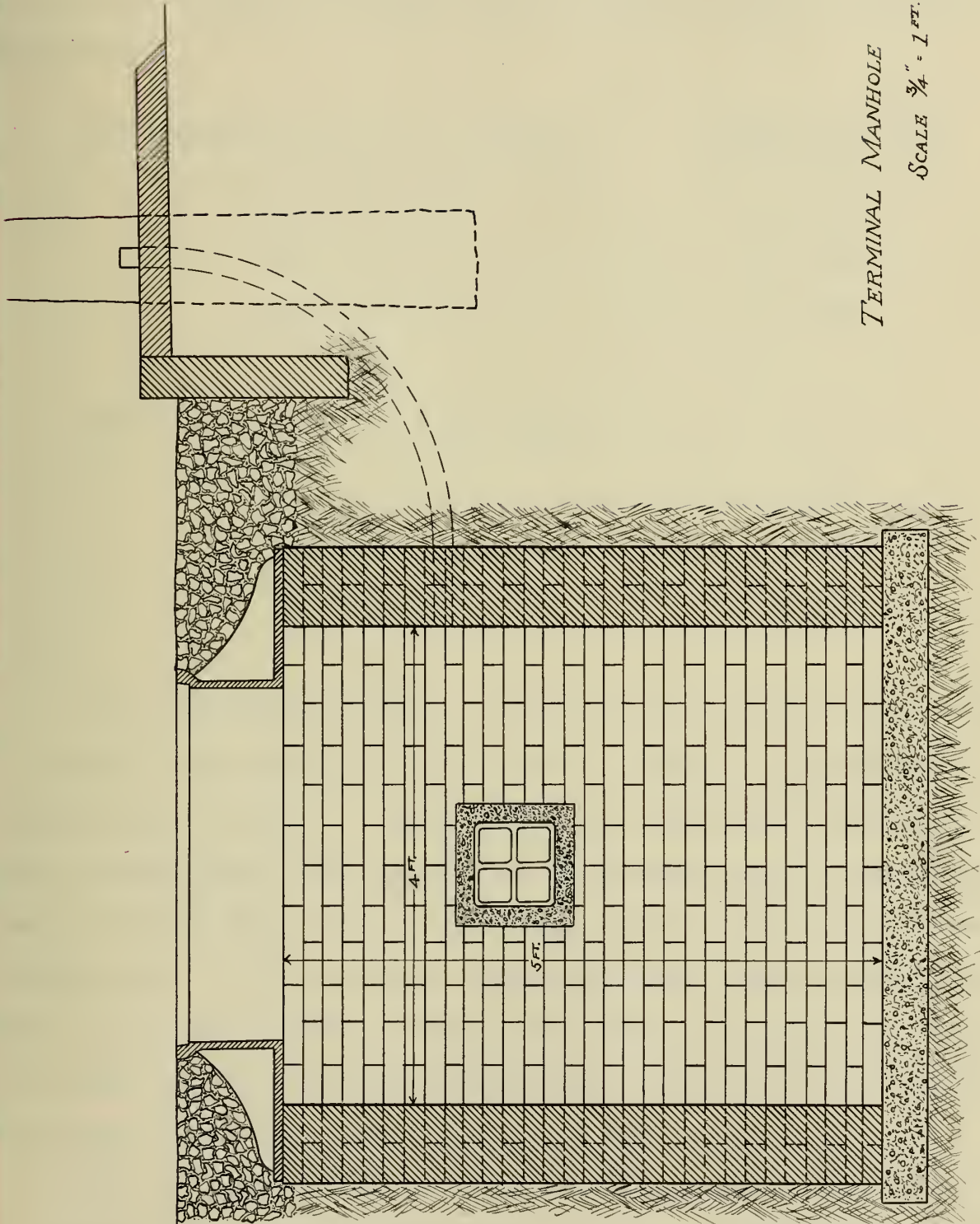
One Two Duct Conduit,

From Capitol to point C (Map No. 1). Distance of 800 feet, contains one No. 10 two conductor cable and one No. 6 three conductor cable. 2 manholes.



ARRANGEMENT OF MANHOLES.

TERMINAL MANHOLE
SCALE $\frac{3}{4}" = 1 \text{ FT.}$



LEAD COVERED CABLE. The lead covered cable to be used in construction is shown on Plates XII and XIII and may be summarized as follows:--

Two Conductors (B. & S. Gauge).	Number of Feet.
---------------------------------	-----------------

No. 2.....	600
No. 8.....	3,300
No. 10.....	800

Three Conductors (B. & S. Gauge).

No. 0.....	800
No. 6.....	4,100
No. 10.....	3,300

POLE LINE CONSTRUCTION. The pole line construction consists of poles varying from 35 to 60 feet in length, as specified in the accompanying sheets. These poles are spaced 120 feet apart, and are equipped with four and six pin cross arms, pins, and insulators as specified; the wiring in all cases being triple braid weather-proof wire. The pole line construction has been divided into several parts, as follows:-- Line from corner of Johnson and Park Sts. to corner of Mifflin and Fairchild Sts. (From A to B on Map No. 1). Distance 4,400 feet, poles spaced 120 feet apart, making $37 + 10\% = 41$ poles. These poles to be 50 feet long with 8 inch tops and set 7 feet in the ground. Each pole is to be equipped with two six pin cross arms and eight deep groove, double petticoat insulators. On Johnson St., where the line crosses Bassett St., use two 55 foot and

two 60-foot poles on each side, in order to cross over telephone wires on Bassett Street.

No. of 50-foot poles	33
No. of 55-foot poles	4
No. of 60-foot poles	4
No. of six-pin cross arms.	82
No. of insulators	328
No. of pins	328

The 8 wires carried are:-

No. 3 B. & S. gauge	2
No. 10 B. & S. gauge	3
No. 6 B. & S. gauge	3

Line from corner of Webster St. and Washington Ave. to intersection of Washington Ave. and C. & N. W. R'y (from C to E on Map No. 1). Distance 6,600 feet, poles spaced 120 feet apart, making $55 + 10\% = 61$ poles. These poles to be 50 feet long with 8-inch tops and set 7 feet in the ground. Each pole to be equipped with one four-pin cross arm, three pins and three deep groove, double petticoat insulators. At the intersection of Washington Ave. with C. & N. W. R'y (point E on Map No. 1), four 55-foot and four 60-foot poles should be used in getting by Fuller & Johnson works, crossing telegraph wires, etc.

No. of 50-foot poles	53
No. of 55-foot poles	4
No. of 60-foot poles	4

No. of Four pin arms.....	61
No. of Insulators.....	133
No. of Pins.....	183

The 5 Wires Carried are:-

No. 6 B. & S. Gauge.....	3
No. 10 B. & S. Gauge.....	2
(to point D).	

Line from intersection of Washington Ave. and C. & N. W. R'y to Mendota Hospital, (from E to Mendota Hospital on Map No. 1). Distance 22,500 feet; poles spaced 120 feet apart, making $188 + 10\% = 207$ poles. These poles to be 35 foot poles with 7 inch tops set 6 feet in the ground. Each pole to be equipped with one four pin cross arm, three pins, and three deep groove, double petticoat insulators. About 10 % of the poles should be 40 feet long because of trees and other obstacles.

No. of 35 foot poles.....	133
No. of 40 foot poles.....	19
No. of Four pin cross arms.....	207
No. of Insulators.....	321
No. of Pins.....	621

The 3 Wires Carried are:-

No. 6 B. & S. Gauge.....	3
--------------------------	---

Branch from Mendota Hospital pole line to Governor's residence (from D to 3 on Map No. 1). Distance 2,600 feet; poles spaced 120 feet apart, making $22 + 10\% = 25$ poles. These poles to be 50 foot

poles with 8-inch tops and set 7 feet in the ground. Each pole to be equipped with one four-pin cross arm, two pins, and two deep groove, double petticoat insulators.

No. of 50-foot poles	25
No. of four-pin cross arms	25
No. of pins	50
No. of insulators.	50

The 2 wires carried are:-

No. 10 B. & S. gauge	2
--------------------------------	---

From State and Mary streets to Dairy Building (from L to 13 on Map No. 2). Distance 1,650 feet; poles spaced 120 feet apart, making $13 + 10\% = 15$ poles. These poles to be 35 feet long with 7-inch tops and set 6 feet in the ground. Each pole to be equipped with two four-pin cross arms, five pins, and 5 deep groove, double petticoat insulators. This estimate includes tap to Horticultural Hall (No. 19).

No. of 35-foot poles	15
No. of four-pin cross arms	30
No. of pins	75
No. of insulators	75

The 5 wires carried are:-

No. 2 B. & S. gauge	2
No. 0 B. & S. gauge	3

From point 16 on Dairy Building line to Observatory (17). Dis-

SUMMARY OF POLE LINE MATERIAL:-

No. of 35 foot poles.....	227
No. of 40 foot poles.....	19
No. of 50 foot poles.....	111
No. of 55 foot poles.....	8
No. of 60 foot poles.....	8
No. of Four pin cross arms.....	367
No. of Six pin cross arms.....	82
No. of Pins.....	1,365
No. of Insulators.....	1,365

SUMMARY OF WEATHERPROOF WIRE. The weatherproof wire to be used in connection with the pole line construction is shown on Plates XII and XIII, and may be summarized as follows:-

Size of Wire. (B. & S. Gauge).	Number of Feet.	Number of Pounds.
0.....	5,000.....	2,000
2.....	9,900.....	2,500
5.....	600.....	90
6.....	100,500.....	11,350
8.....	13,200.....	1,100
10.....	22,100.....	1,200
Total number of pounds.....		18,240

TRANSFORMERS. These have been arranged to feed two or more buildings whenever possible. In many instances the load at one building is so large or the building so isolated (or both) that it is necessary to place transformers at individual buildings. For the buildings of the University and the Historical Library, transformers are necessary for lighting only, since motors are to be connected directly to the 500 volt mains. At the Capitol and Mendota Hospital it is necessary to use transformers for both light and power. The transformers necessary at the station will be considered in Part VI. A summary of transformers, showing sizes, location, ratio of transformation, number needed, etc. is given on Plate XVII.

✓

TRANSFORMERS.							REMARKS.
LOCATION.	CIRCUITS SUPPLIED	CIRCUIT.	NO. OF TRANSFORMERS	CAPACITY OF EACH IN KILOWATTS	PRIMARY PRESSURE (VOLTS)	SECONDARY PRESSURE (VOLTS)	
CENTRAL STATION	CENTRAL STATION	LIGHT	1	4	500	100 - 200	STATION LIGHTS
"	CAPITOL	"	2	30	500	5000	MAY BE REPLACED BY ONE 75 K.W. TRANSFORMER.
"	"	POWER	3	12	500	5000	THREE PHASE TRANSMISSION.
"	MENDOTA	LIGHT & POWER	3	20	500	5000	"
CAPITOL	CAPITOL	LIGHT	2	30	5000	100 - 200	THREE WIRE SYSTEM.
"	"	POWER	3	42	5000	220	RUN 220 VOLT MOTORS.
"	GOVERNOR'S RES.	LIGHT	1	2	5000	1000	TAP FROM MENDOTA CIRCUIT.
GOVERNOR'S RES.	"	"	1	2	1000	100 - 200	
MENDOTA	MENDOTA	LIGHT & POWER	3	20	5000	100 - 200	THREE WIRE SYSTEM FOR LIGHTING. MOTORS RUN ON 220 VOLTS.
GYMNASIUM.	GYMNASIUM.	LIGHT	1	15	500	100 - 200	
STATE HIST. LIBRARY	STATE HIST. LIBRARY	"	2	25	500	100 - 200	TWO INDEPENDENT SINGLE PHASE CIRCUITS, AND TWO TRANSFORMERS.
SCIENCE HALL	SCIENCE HALL	"	1	10	500	100 - 200	
MACHINE SHOP.	MACHINE SHOP	"	1	10	500	100 - 200	
CHEMICAL LAB.	CHEMICAL LAB	"	1	2	500	100 - 200	
LAW BUILDING.	LAW BUILDING	"	1	5	500	100 - 200	
LIBRARY HALL	LIBRARY HALL	"	1	5	500	100 - 200	
LADIES HALL.	LADIES HALL	"	1	15	500	100 - 200	
ENGINEERING BLDG.	ENGINEERING BLDG.	"	1	10	500	100 - 200	
TUNNEL NEAR NORTH HALL	NORTH & SOUTH HALLS	"	1	2	500	100 - 200	THE PRIMARY TO BE CONNECTED TO UNIVERSITY HALL 500 VOLT MAINS.
UNIVERSITY HALL	UNIVERSITY HALL	"	1	5	500	100 - 200	
OBSERVATORY.	OBSERVATORY	"	1	$\frac{1}{2}$	500	100 - 200	
DAIRY BLDG.	HORT. & DAIRY BLDGS	"	1	$1\frac{1}{2}$	500	100 - 200	SUPPLIES BOTH BUILDINGS AND IS LOCATED BETWEEN THEM.
UNIVERSITY BARN.	UNIVERSITY BARN	"	1	1	500	100 - 200	
DAIRY BARN.	DAIRY BARN.	"	1	1	500	100 - 200	

TOTAL CAPACITY OF TRANSFORMERS = 453 KILOWATTS.

The Building.

The general design of the building is due primarily to Mr. J. T. W. Jennings. The character of the ground, levels, etc., are shown on the Contour and Profile Maps on Sheet No. 3.

The building is long, narrow and low, with a flat roof, set upon the shore of Lake Mendota under the bluff just north of the University Shops. The site includes that now occupied by the present pump house, and space is provided in the plans for the location of the pumps in a room just west of the generating room. The general plan and north elevation of the building are shown on Sheet No. 4. It is designed to face the lake and the boiler room, which is 51 feet wide, occupies the eastern portion, while the generator room, which is 51 feet wide, occupies the western portion. The east end of the building outs into the bluff, thus permitting the dumping of the coal into the coal bunkers through hatchways directly from the upper level.

The foundations rest upon oak piles driven to refusal. The heads of these are capped with concrete below the low water line. The concrete cap under the chimney is further stiffened with 12 inch steel beams. Above the footings and below the water-table, or below ground, the foundation walls and retaining walls are to be laid with Waukesha stone, large block rubble, laid with Milwaukee cement mortar, (one part cement to three parts of sand). The water-tables, sills, and coping are of Bedford stone; the backing brick is common local brick and the face brick is Gray Hydraulic Pressed brick costing \$24.00 per thousand.

The floors are to be of Portland cement concrete, composed of one part of Portland cement, two parts of sand, and five parts of

broken stone from local quarries. This is to be finished off with a granitoid top composed of one part Portland cement, one part sand, and five parts crushed granite screenings, the same to be laid in four foot squares.

The interior walls will show the brick with joints neatly struck for pointing. The posts and girders will be of steel, the posts to be built of "Z" sections and the girders to be lattice steel angle girders. Deck beams will be of steel, the space between beams being arched with brick and the spandrels of the archings filled to a height of four inches above the crown of arches with Portland concrete similar to that used for floors. The whole is to be finished with a granitoid top the same as for floors. The skylights, lighting the engine and boiler rooms, will have galvanized iron frames and one-half inch ribbed plate glass glazing. The hatchways are to have cast iron frames and covers, surrounded with protecting railings of gas piping.

All glazing is to be done with American A.A. D.T. glass. The pediments over doorways, panels and pilaster capitals, and ornaments are to be of terra cotta, in color to match the brick work. All exterior wood and iron work is to be painted with three coats of lead and oil paint, in tints to be selected. The interior wood work is to be given three coats of lead and oil, and the interior brick work is to be sized and painted with three coats of lead and oil.

CHIMNEY. The chimney will make a striking feature in the landscape when viewed from any direction, and it is, therefore, designed to give the impression of a great circular shaft with a graceful taper, and some architectural decorations.

The chimney is to be built of hard burned sewer brick, faced with the same kind of pressed brick as is used for the building walls. The pedestal and shaft of the chimney will be ornamented with terra cotta and moulded brick (more extensively than is shown in the drawing) and the bell of the chimney finished with terra cotta and moulded brick and is to be provided with a cast iron cap. The chimney walls are to be double throughout, the inner of flue wall to be independent of the outer wall, providing for expansion, etc.

The chimney has a cylindrical inside diameter of 9 feet, and a total height of 185 feet from the boiler house floor. The general dimensions of the chimney have been worked out by Professor Bull and the size is ample for a boiler capacity of 2,500 H. P., or more. Computations made according to the formulas proposed by William Kent^{*} show that the chimney is of sufficient size for a boiler capacity of about 2,700 horse-power. In these formulas, Kent has considered a commercial H. P. to demand the consumption of 5 pounds of coal per hour. Computations, according to Molesworth's formula, show a capacity of about 10,500 pounds of coal burned per hour. Assuming 4 pounds of coal burned per hour as 1 H. P., this gives about 2,600 H. P. boiler capacity.

The chimney is 20 feet square at the base which is in accordance with the general rules of design which require that the outside diameter at the base should not be less than one-tenth of the height.

*

"Chimney Design" by W. W. Christie, Chapter III.

It is almost exactly the size of the Montreal (Canada) Street Railway Company's Williams Street Power House chimney.* This (built in 1894) is 190 feet high above the firegrate, with a flue 9 feet in diameter. It has a square pedestal base which is 18 feet square outside. This chimney has connected to it 3,000 H. P. of boiler capacity.

The chimney is probably somewhat larger than is necessary and might, perhaps, be cut down to 8 feet in diameter and 175 feet in height. However, it should be remembered that the location is not of the best for draft, as the power house is under a bluff and the chimney is to some extent shut off, because of some neighboring buildings on still higher ground, rising above the top of the chimney.

The Boiler Room.

The boiler capacity (used for heating purposes) now installed in the present central heating plant is about 1,100 H. P. The necessary boiler capacity for steam heating under the new conditions was estimated (by Professor Bull) to be 1,500 H. P. The maximum station load within two years will not be more than about 300 K. W., which would correspond to an engine capacity of 450 H. P., and for the present needs a boiler capacity of 500 boiler H. P. would be ample

*

"Chimney Design" by W. W. Christie, page 117.

for the electric plant if it were operated independently. The total boiler capacity proposed for immediate needs is 1,975 H. P., which is almost equal to the sum of the capacities required for heating purposes and for the electric plant, taken separately. This large capacity certainly permits of a very wide margin of safety for two reasons.

First, an increase of efficiency would result in the steam heating system by the remodelling of the tunnels, by the use of better and larger boilers, by the better facilities offered at the new boiler house, etc.

Second, the maximum electric load occurs between 5:00 P. M. and 8:00 P. M., at a time of the day when there is comparatively little call for steam heating.

It is reasonably certain that the assumed boiler capacity will permit of at least one unit of 250 H. P. remaining idle without overloading the other units, even under conditions of maximum load.

Since there are several comparatively new boilers of fair size in the present heating plant, it is proposed to move certain ones of these to the new plant. These boilers are shown in the two banks at the east end of the boiler house. The first bank consists of three tubular boilers rated at 125 H. P. each. The second bank consists of one 150 H. P. "Standard" water tube boiler and one 200 H. P. "Babcock and Wilcox" water tube boiler.

It is proposed to install 1,250 H. P. capacity in addition to make up the 1,975 H. P. deemed necessary. These will be water tube boilers rated at 250 H. P. each. The new boilers are shown in three banks directly west of the old ones. The first two banks are of

500 H. P. each and the third contains one 250 H. P. boiler. Space is left for the installation of 750 H. P. additional boiler capacity. Further additions may be made, if necessary, by replacing the old boilers at the east end of the boiler room and extending the building to the east. The new boilers are to be provided with chain grates, and hoppers are to be constructed for feeding the coal into the stokers. A sectional drawing showing the arrangements for the economical handling of the coal is shown on Sheet No. 3.

HEADERS. Since the boiler pressure for steam heating is not more than 50 pounds per square inch, while that for the electric plant is about 150 pounds per square inch, independent headers are used for these two purposes. The steam heating header is arranged so that it may be connected to any or all boilers. The new boilers only are connected to the header for the electric plant.

PIPING. The piping for steam heating purposes was determined by Professor Bull, and has been represented according to his specifications.

The size of the steam pipe for the electric plant has been calculated for an average steam velocity of 80 feet per second. This is rather low (80 feet per second being a more average value) but the main is quite long and has two right angle bends and it was deemed advisable to have a steam main large enough to ensure a uniform flow of steam throughout the stroke of the engines.

COAL BUNKERS. As has been indicated in the description of the building, coal bunkers have been provided with a storage capacity of two thousand tons. This is one-third of the total yearly consumption and is considered ample to provide against all contingencies which may arise.

The Generating Room.

Three assumptions were made in Parts II and III which affect the general design of the electric station. These may be briefly stated as follows:-

First, a generator pressure of 500 volts was considered most advisable because about one-half of the total power is to be transmitted by means of tunnel wiring, which will not permit of a much higher pressure if rubber covered wires are used with no additional protection.

Second, the three phase alternating current system was adopted because of the larger power load and because of the long transmission line to Mendota Hospital.

Third, the line pressures to Mendota Hospital and to the Capitol were taken at 5,000 volts. Calculation showed that with this pressure the required power could be transmitted to Mendota Hospital with a ten per cent. loss, using No. 6 B. & S. gauge wires. Since this is as small a wire as it would be desirable to use under the circumstances, there is no particular advantage in using a higher pressure. The pressure on the transmission line to the Capitol has been taken at 5,000 volts also, since it would simplify matters to use the same pressure for both lines.

GENERATORS. Although the maximum load within five years will be about 450 kilowatts, the immediate maximum load will probably be about 300 kilowatts. This load can be taken care of by two 150 K.W. generators. Since it is highly desirable and practically essential in this case to have an additional unit, a generating capacity con-

sisting of three 150 K. W. generators and one 50 K. W. generator will be necessary for present requirements, the latter being installed for night use.

Since more than half of the power is to be used for lighting purposes, and since a number of arc lamps are to be operated, it is desirable to have a comparatively high frequency and sixty cycles per second has been taken as this is a standard frequency for this kind of work.

The generator capacity will, therefore, consist of three 150 K. W., 500 volt, three phase, 60 cycle, alternating current generators; and one 50 K. W., 500 volt, three phase, 60 cycle, alternating current generator. These generators are to be directly coupled to engines as indicated below and as shown on the drawing of the central station (Sheet No. 4). Each generator is to be supplied with its own exciter.

ENGINES. The engines for the 150 K. W. generators are to be of 225 H. P. capacity each, and the speed of these units should be about 175 revolutions per minute. The engine for the 50 K. W. generator is to be of 75 H. P. capacity, and the unit is to have a speed of about 300 revolutions per minute.

The engines are to be compound condensing, and vertical cross-compound engines are to be preferred because of economy of floor space. The 225 H. P. engines should have an economy of 20 pounds of steam per indicated H. P. per hour, and the 75 H. P. engine should have an economy of 22 pounds of steam per indicated H. P. per hour.

The steam pressure on the high pressure cylinders is to be about 150 pounds per square inch. Receivers, furnished with reheating coils, are to be placed between high and low pressure cylinders.

These receivers should have a volume at least one and one-half times the volume of the high pressure cylinder in each case. Because of advantages in experimental work, these reheaters should be capable of superheating the steam furnished the low pressure cylinders.

Because of the great advantages to be derived in educational work, it is desirable that the cylinder ratios be different for the three 225 H. P. engines. Suggested ratios may be taken at 3 to 1, 5 to 1, and 7 to 1.

ADDITIONAL UNITS. In the design of the generating room, sufficient space has been left for the installation of a fourth 150 K. W. unit, which will probably be necessary within five years. Other units may be added by extending the building to the west.

FOUNDATIONS. The foundations for the engines and generators have been included in the building design, and the estimates of costs of foundations are included in the estimates of the cost of the building. The foundations are to be made of solid Portland cement concrete, rather poor in cement and rich in sand and stone. These foundations are to extend at least six feet below the engine room floor.

CONDENSERS, PUMPS, ETC. Condensers, separators, pumps, hot well, etc. are to be installed and connected up, and the plant is to be complete in every particular. The general arrangement of this auxiliary apparatus has been indicated in the drawing of the central station.

Surface condensers are to be installed, because condensing water is available in any quantity and also because these condensers are best adapted to experimental work. There is to be one condenser of sufficient capacity furnished for each engine. There shall be at

least 3 square feet of cooling surface per I. H. P. The temperature of the cooling water at Madison may be taken at 70° F. and an allowance of twenty-five times the weight of steam used by the engine per hour at maximum load, must be made for cooling water. Each condenser is to be supplied with a single acting air pump and a centrifugal circulating pump.

SEPARATORS. Each engine is to be furnished with a separator which shall be placed in the steam pipe leading to the high pressure cylinder. These separators shall show an efficiency of ninety per cent., with steam of 10 per cent. moisture.

HOT WELL. A hot well is to be constructed having a capacity of at least 250 cubic feet. This will provide for operation of the station at full load for at least one hour without pumping from the hot well.

SWITCHBOARD. There is to be installed a polished marble switchboard of standard construction. This switchboard is to consist of white Italian marble panels two inches thick with one-half inch bevelled edges. The panels are to be properly supported on a rigid iron frame work of "L" section. One panel is to be installed for each generator, one panel for each two power circuits (three phase), and one panel for each two lighting circuits (single phase). There will, therefore, be four generator panels required at the beginning. There will also be required four feeder panels for the power circuits and four feeder panels for the lighting circuits. The high tension lighting and power circuits leading to the Capitol and to Mendota Hospital will require three additional panels. The various feeder circuits were shown on Plate XI. and are as follows:-

Lighting Circuits (single phase).

To the Machine Shops, Electrical Laboratory
and the Chemical Laboratory.

To the Historical Library and Gymnasium.

To the Historical Library.

To Science Hall and the Engineering Building.

To Library Hall, Ladies' Hall, and the Law Building.

To North Hall, South Hall, and University Hall.

To the Observatory, Dairy Building and Farm Buildings.

To the Capitol and Governor's Residence.

Power Circuits (three phase).

To the Machine Shops.

To the Historical Library.

To Science Hall and the Engineering Building.

To Ladies' Hall and the Law Building.

To the Dairy Building and Farm Buildings.

To the Capitol and Governor's Residence.

To Mendota Hospital.

The instruments, switches, etc., for the generator and feeder circuits are mounted on and form a part of these panels. Additional generators and feeders may be provided for at any time by installing additional panels without interruption of service. The general design of the switchboard is shown on Sheet No. 5.

TRANSFORMERS. Transformers are to be provided at the station for raising the pressure to 6,000 volts for the purpose of transmitting power to the Capitol, Governor's residence and Mendota Hospital. These transformers are fully indicated in Plate XVII.

POTENTIAL REGULATORS. Potential regulators are to be installed for maintaining uniform pressure on the lighting mains. These will be installed at the station except in the case of the Mendota Hospital end. No potential regulators are provided for the power circuits. The regulators are to be designed for a frequency of 60 cycles per second and to give a pressure range of ten per cent. One regulator of each kind indicated, is required.

Line Pressure.	Number of Phases.	Location.	K. W. Capacity.
500	1.....	Central Station.....	70
500.....	1.....	Central Station.....	60
500.....	1.....	Central Station.....	60
5,000.....	1.....	Central Station.....	100
5,000.....	3.....	Mendota Hospital.....	60
Total Capacity.....			350

(VII)

ESTIMATES OF COSTS.

As has been stated in the introduction, the estimates of costs of the building and chimney were made by Mr. Jennings, while those concerning the steam heating and the boiler room (including steam pipe and pipe covering to the generating room) were the work of Professor Bull.

Building and Chimney.

The estimates were based upon the following:-

Piles driven at \$5.00 each.

Footings of Portland concrete.

Foundations and retaining walls of Waukesha stone in
Milwaukee cement mortar.

Face brick, \$26.00, pressed brick.

Common brick, good local brick.

Floors, Portland cement and granitoid top.

Posts and deck beams of steel.

Deck, brick arches with Portland cement, granitoid top.

Skylights, American, double thickness in windows and doors.

Ornaments, Terra Cotta.

Cut stone, Bedford.

Moulded string course of moulded brick.

The estimates are as follows:-

Piling breakwater.....	\$1,800.00
Rip Rapping with lake boulders.....	1,000.00
Filling.....	2,000.00
	<u>\$4,800.00</u>
Chimney complete.....	\$12,000.00

Building Proper.

Piling.....	\$2,800.00
Excavating.....	1,500.00
Masonry, foundations, retaining walls, coal storage bins, etc., with concrete footings.....	11,500.00
Cement floors (including deck).....	3,800.00
Structural steel and iron, including gallery....	9,000.00
Common brick work and cut stone.....	9,200.00
Pressed brick.....	4,000.00
Terra Cotta.....	2,500.00
Carpenter and mill work.....	3,500.00
Skylights, including rail.....	1,000.00
Amount carried forward.....	<u>\$48,800.00</u>
Drainage and plumbing.....	1,500.00
Painting.....	1,000.00
Contingencies.....	2,500.00
	<u>\$53,800.00</u>

Recapitulation:-

Preparing site	\$4,800.00
Chimney complete	12,000.00
Building complete.	53,800.00
Total	\$70,600.00

Boilers and Accessories

This estimate includes considerable piping for steam heating, as well as several hundred feet of tunnel construction. Otherwise the items follow quite directly from matter already presented. The estimate is as follows:-

Moving and resetting old boilers	\$2,500.00
New boilers, 1250 H.P. at \$21.00 per H.P.	26,250.00
Breeching and hoppers	2,450.00
Economizer	6,000.00
Piping	8,500.00
Pipe covering.	1,900.00
Valves	1,100.00
Receivers.	400.00
Pumps	450.00
Tunnel construction(330 feet at \$7.00 per ft.)	2,310.00
Steam traps, grease traps, etc.	250.00
Total	\$ 52,110.00

The Electric Plant.

In making the estimates for the electric plant it has been necessary to calculate the cost of the transmission lines in detail. These costs will be considered first and then a general summary will be made.

TUNNEL CONSTRUCTION. The rubber covered wire necessary for use in the tunnels is estimated as follows:-

Size of Wire. (B. & S. Gauge)	No. of Feet.	Price per 1,000 feet.	Cost.
No. 0.....	9,800.....	\$149.50.....	\$1,465.10
No. 2.....	11,000.....	89.15.....	980.65
No. 3.....	3,000.....	72.88.....	318.64
No. 4.....	6,500.....	60.17.....	391.10
No. 6.....	4,200.....	43.50.....	182.70
No. 8.....	1,000.....	28.57.....	28.57
No. 10.....	1,700.....	21.60.....	36.72
Total.....			\$3,301.48

The cost of erection of the tunnel lines, including labor and all material excepting wire, was estimated at \$25.00 per 1,000 feet of wire.

Erection of 37,000 feet of Tunnel Wiring.....\$925.00

CONDUIT CONSTRUCTION. Under this heading is considered the cost of lead covered cable, and the cost of conduit construction complete including the cost of drawing in of cables.

The cost of the necessary lead covered cable is based upon prices quoted by the Standard Underground Cable Company, and is as follows:-

Size of Wire (B. & S. Gauge)	Number of Conductors.	Number of Feet.	Cost.
No. 2.....	2.....	600.....	\$192.00
No. 8.....	2.....	3,300.....	660.00
No. 10.....	2.....	800.....	136.00
No. 0.....	3.....	600.....	348.00
No. 6.....	3.....	4,100.....	1,230.00
No. 10.....	3.....	3,300.....	726.00
Total.....			\$3,292.00

The cost of conduit is based upon figures furnished by John T. MoRoy, manufacturer of the MoRoy conduit, and includes the conduit laid complete, ready for the drawing in of cables. The two duct conduit is estimated at 40 cents per running foot of conduit, and the four duct conduit is taken at 60 cents per running foot. The cost of manholes was taken at \$40.00 per manhole, and the cost of drawing in cables was estimated at 5 cents per foot of cable. These figures were also furnished by Mr. MoRoy.

The estimate is as follows:-

One Two Duct Conduit,

From University Hall (No. 18) to point L (Map No. 2).

Distance of 600 feet; 2 manholes.....\$320.00

One Four Duct Conduit,

From Central Station (No. 1) to point A (Map No.2).

Distance of 2,200 feet; six manholes.....1,560.00

One Four Duct Conduit,

From point B to Capitol (Map No. 1).

Distance of 1,100 feet; three manholes.....780.00

One Two Duct Conduit,

From Capitol to point C (Map No. 1).

Distance of 800 feet; 2 manholes.....400.00

Cost of drawing in Cable, 9,400 feet

at 5 cents per foot.....470.00

Total.....\$3,530.00

POLE LINE CONSTRUCTION. The pole line proper has been calculated at a certain price per pole, which estimate includes the cost of a pole set up complete with cross arms, pins, and insulators, ready for the erection of the line wires. These estimates were based upon costs of similar constructions in this locality.

Number of Poles.	Length of Pole in Feet.	Cost per Pole.	Cost.
227.....	35.....	\$12.50.....	\$2,724.00
19.....	40.....	15.00.....	285.00
111.....	50.....	25.00.....	2,775.00
8.....	55.....	30.00.....	240.00
8.....	60.....	35.00.....	280.00
Total.....			\$6,304.00

The cost of the necessary weatherproof wire for the pole line was estimated as follows:-

Size of Wire (B. & S. Gauge).	Number of Feet.	Number of Pounds.
No. 0.....	5,000.....	2,000
No. 2.....	9,900.....	2,500
No. 5.....	690.....	90
No. 6.....	100,500.....	11,350
No. 8.....	13,200.....	1,100
No. 10.....	22,100.....	1,200
Total number of Pounds.....		18,240

18,240 pounds of Weatherproof Wire at 21 cents per pound.....\$3,780.00

The cost of erection of line wire was taken at \$5.00 per 1,000 feet of wire.

Erection of 151,000 feet line wire.....\$755.00

TRANSFORMERS AND POTENTIAL REGULATORS.- A list of the necessary transformers is given on Plate XVII, and a summary of the required potential controllers is given on page 77. The transformers were estimated at \$10.00 per K.W. and the potential controllers at \$6.00 per K.W.

Cost of transformers, 450 K.W. at \$10.00 \$4,500.00

Cost of potential regulators, 350 K.W. at \$6 . . . 2,100.00

The cost of engines set up complete is taken at \$15.00 per H.P. The condensers, separators, hot well, pumps, etc., are grouped together and estimated at \$6.00 per H.P. set up complete. The generators and exciters set up complete are taken at \$20.00 per K.W., and the cost of switchboard and station wiring is estimated at \$10. per K.W.

A summary of the costs of the electric plant may be made as follows:-

Engines set up complete -

750 H.P. at \$15.00 per H.P. \$11,250.00

Condensers, separators, hot well, pumps, etc.,
set up complete

750 H.P. capacity at \$6.00 per H.P. 4,500.00

Generators and exciters, set up complete

500 K.W. capacity at \$20.00 per K.W. 10,000.00

Switchboard and station wiring, complete

500 K.W. capacity at \$10.00 per K.W. 5,000.00

Transformers, installed complete

450 K.W. at \$10.00 per K.W. 4,500.00

Potential controllers, installed complete

350 K.W. capacity at \$6.00 per K.W. 2,100.00

Conduit construction, including the drawing

in of cables 3,530.00

Lead covered cables	\$3,292.00
Rubber covered wire	3,300.00
Weatherproof wire	3,730.00
Erection of rubber covered wire	950.00
Pole lines, complete and ready for erection of wire	6,304.00
Erection of weatherproof wire	755.00
Five ton traveling crane	1,500.00
Telephone circuit to the Capitol and Mendota Hospital	250.00
Additional 10 per cent for engineering and incidentals	6,000.00
Total cost (exclusive of building and boilers)	\$66,986.00

General Summary of Costs

Building and chimney, complete	\$70,600.00
Boilers and boiler room equipment, complete. . .	52,110.00
Electric Plant complete(exclusive of boilers). .	66,986.00
Total cost of Central Plant	\$189,696.00

(VIII)

FINAL ESTIMATES OF ANNUAL COST OF OPERATION

The estimate of the annual cost of operation within five years by the proposed system (given in Part IV) has been increased slightly. This increase occurs mainly in items such as extra labor, repairs, etc., which were thought to be somewhat under what would be required for the new plant. The estimates of the annual cost of operation within five years under present conditions have remained unchanged.

Present Conditions

The annual cost under present conditions may be summarized as follows:-

Total present operating expenses	\$33,000.00
--	-------------

Total prospective increase (within five years)	7,500.00
---	----------

Total	\$40,500.00
-----------------	-------------

New System.

The annual cost under the new system may be taken as follows:-

Coal for Heat, Light, and Power.....	\$13,500.00
Wages (nine men all told).....	5,040.00
Extra Labor.....	500.00
Boiler Inspection and Insurance.....	300.00
Heating Plant Supplies and Renewals.....	800.00
Electric Plant Supplies and Renewals.....	1,500.00
Sundry Disbursements.....	1,000.00
Superintendence and Office Expenditures.....	1,500.00
Total.....	\$29,100.00

Economy of New Service.

Total Annual Cost by Present System.....	\$40,500.00
Total Annual Cost by Proposed System.....	29,100.00
Annual Saving by Proposed System.....	\$11,400.00

(IX)

CONCLUSION.

The general summary made in Part VII showed a somewhat larger total cost than was anticipated at the beginning of the investigation. A consultation resulted in the decision that the total cost should be kept within the sum of one-hundred and fifty thousand dollars, and in order to accomplish this it was decided, after due consideration, to cut down the various estimates, as shown below.

The Building.

It was decided that the forty-eight hundred dollars estimated as necessary for the preparation of the site might be cut out without any very serious results. The cost of the chimney was reduced two thousand dollars by considering a slightly smaller chimney and a somewhat cheaper construction. The piling for the building foundations was omitted as it was considered that the character of the soil is such that this would not be essential. The general reduction in the size of the building resulting from the reduction in boiler and electric generating capacity (considered below) caused a reduction in many of the other items, especially in steel construction and foundations. The substitution of common brick for pressed brick

and the omission of the item for terra cotta also made a considerable saving. The revised estimate of the cost of the building is as follows:-

Chimney.....	\$10,000.00
Masonry foundation walls, retaining walls, coal storage bins.....	10,000.00
Excavating.....	1,200.00
Cement floors (including deck).....	3,200.00
Structural steel and iron.....	7,000.00
Common brick and out stone.....	7,100.00
Pressed brick.....	1,000.00
Carpenter and mill work.....	2,700.00
Skylights, including rail.....	800.00
Drainage and plumbing.....	1,200.00
Painting.....	800.00
Total.....	\$45,000.00

Boilers and Boiler Room Equipment.

In this estimate the principal out has been in the cost of boilers. The estimate of \$21.00 per H. P. seemed somewhat excessive and this figure was reduced to about \$17.00 per H. P. Five thousand dollars was considered sufficient to expend upon an economizer. The pipe, pipe covering, fittings, etc., are grouped together and a out of about fifteen hundred dollars is made in these items. The estimate for new tunnel construction has been out out, as it was considered that this might be constructed with other funds.

The revised estimate follows:-

Piping and covering.....	\$10,400.00
Receiver.....	200.00
Feed pumps.....	450.00
Economizer.....	5,000.00
New Boilers (1,250 H. P.).....	31,000.00
Breeching and coal hoppers.....	2,450.00
Moving old boilers.....	3,500.00
Total.....	\$42,000.00

The Electric Plant.

The electric plant has been cut down by one 150 K. W. unit, the estimates in other particulars remaining practically unchanged. The plant as cut down is just sufficient to provide for the amount of electric and gas lighting and of electric and hydraulic power which is now in use at the several institutions, and for an additional elevator in the Capitol. It does not make provision for any spare generating capacity to be put into use in case of an accident to either of the 150 K. W. generating units, and it also does not make provision for supplying electric power to the University Shops or other buildings which are now provided with steam power. Provisions for supplying electric power at these points and for supplying the natural growth in the demand for electric light and power during the next five years, can be made only by adding new generating units of 150 K. W. capacity, up to an ultimate addition of two more units, as the demand presents itself. To assure a satisfactory continuity of

service one of these additional units should be installed inside of two years, especially in view of the rapid growth of the University. An accident to one of the units while only two are in the plant would probably plunge the University into darkness, since the plant as cut down will barely supply the existing demand for electric power and lighting during legislative years. This condition is permissible only on the ground of reducing the first cost of the plant. The revised estimate is as follows:-

Engines set up complete.	
525 H. P. at \$15.00 per H. P.....	\$7,875.00
Condensers, Separators, Hot Well, Pumps, etc. set up complete; 525 H. P. capacity at \$5.00 per H. P.....	2,825.00
Generators and Exciters, set up complete. 350 K. W. capacity at \$20.00 per K. W.....	7,000.00
Switchboard and Station Wiring, complete. 350 K. W. capacity at \$10.00 per K. W.....	3,500.00
Transformers, installed complete. 450 K. W. capacity at \$10.00 per K. W.....	4,500.00
Potential Controllers, installed complete. 350 K. W. capacity at \$6.00 per K. W.	2,100.00
Conduit Construction, including the draw- ing in of cables.....	3,450.00
Lead Covered Cables.....	3,292.00
Rubber Covered Wire.....	3,150.00
Erection of Rubber Covered Wire.....	925.00
Pole Lines, complete, ready for erection of wire.....	6,304.00
Erection of Weatherproof Wire.....	755.00

Five ton Traveling Crane, for	\$1,500.00
Telephone Circuit to the Capitol and Mendota Hospital.....	250.00
Total.....	\$1,000.00

The total cost of construction of the Central Plant as cut down
may be summarized as follows:-

Building.....	\$45,000.00
Boilers, etc.....	42,000.00
Engines, etc.....	51,000.00
	\$138,000.00

Additional 8 % for Engineering and

Incidentals.....	11,040.00
------------------	-----------

Total.....	\$149,040.00
------------	--------------





